PART VI

GEOLOGY AND AGRICULTURE

A REPORT

ON

THE GEOLOGY OF LOUISIANA

CONTAINING SPECIAL PAPERS BY DIFFERENT AUTHORS;
BASED ON THE WORK OF THREE FIELD SEASONS,
1900, 1901, 1902

GILBERT D. HARRIS, *Geologist-in-Charge*

ARTHUR C. VEATCH, *Assistant Geologist*

AND

JOV. A. A. PACHECO, *Assistant Geologist*

MADE UNDER THE DIRECTION OF THE STATE EXPERIMENT STATION

WM. C. STUBBS, *Director*

BATON ROUGE, LA.
1902

LOUISIANA STATE UNIVERSITY AND A. AND M. COLLEGE.

The Bulletins and Reports will be sent free of charge to all farmers by applying to Commissioner of Agriculture and Immigration, Baton Rouge, La., or to the Director of the Station, Audubon Park, New Orleans, La.

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OFFICE OF EXPERIMENT STATIONS,
LOUISIANA STATE UNIVERSITY AND A. AND M. COLLEGE,
BATON ROUGE, LA., Mar., 1902.

To His Excellency W. W. HEARD, *Governor of Louisiana, and President of Board of Agriculture:*

Sir: Arrangements have been made with Prof. G. D. Harris, Ph.B., of Cornell University, for the continuation of the Geological Survey of this State. He has had the assistance of Mr. J. Pacheco and Mr. A. C. Veatch. The limited amount of appropriation has prevented the employment of these gentlemen continuously. Accordingly, they have given three months of each year to the energetic prosecution of the work in the field, and have prepared for the press the notes made in the field during their official services elsewhere.

Since our last report a wonderful interest has been created in the geology of Louisiana by virtue of the discovery of oil in this State and in Texas. Again, the question of obtaining artesian water is being discussed by nearly every locality in the State, and the location of the true water-bearing strata underlying this State has been a special study by the survey. Since the discovery of the strata of sand and gravel underlying Southwest Louisiana, and the boring of hundreds of wells which are irrigating thousands of acres of rice, every other section of the State has been deeply interested in finding out the character of the subterranean strata and the possibility of obtaining water. This subject is fully treated in the accompanying pages.

The numerous gushers at Beaumont, Texas, have excited persons in all parts of the State to action. Many wells have been bored in various parts of the State, and numerous companies have been formed for exploiting the State's wealth in this great fuel and illuminant.

Some few efforts have been successful; many have failed. In this report will be found a full discussion of the oil conditions of this State, and it is hoped that the facts given will deter companies from expending large sums of money in the vain hope of

obtaining oils in unfavorable localities where the so-called oil experts have pronounced an abundance of this greasy fluid. A knowledge of the geology of a section is often of valuable aid in determining where not to bore.

The demand for the geological reports of the State is now enormously large. There is a constant stream of immigrants coming to this State, some seeking homes, some fields for investment, and others looking only to speculation. All want the latest developments in regard to soils, minerals, waters, etc.

To meet the existing demands for this information, a sum sufficiently large to permit a continuous and vigorous prosecution of this work, should be made by the next legislature. It will be, perhaps, the most profitable investment that the State could make, and I earnestly recommend to your Excellency such an appropriation.

Louisiana has 45,000 square miles of various geological horizons. She has wonderful resources that await only accurate knowledge of them to be developed into active wealth.

For the special papers included in this report see contents on the preceding page.

Respectfully submitted, WM. C. STUBBS, *Director.*

LETTER OF TRANSMISSION

DR. WM. C. STUBBS, DIRECTOR STATE EXPERIMENT STATIONS, BATON ROUGE, LA.

Sir: I transmit herewith our report of 1902 on the geology of Louisiana. It represents the combined labors of myself and one assistant for three field seasons (1900, 1901, 1902) of about three months each. Most respectfully submitted,

GILBERT D. HARRIS,
Geologist-in-charge.

Office of Louisiana Geological Survey,
Cornell University, Ithaca, N. Y.,
May 20, 1902.

PREFATORY REMARKS

By glancing at the table of "Contents" given a few pages before, it will be apparent that this work is practically a continuation of Part III of our report of 1899; for it consists of special papers by various authors dealing with topics of interest and importance in the development of the geology of the State.

Lack of funds has prevented us from a further prosecution of topographic work; the same cause has prevented the proper collection of oil-well records, records of value almost beyond calculation both to the stratigrapher and practical oil man, but when once lost, lost forever; the same cause has prevented the continuous recording of the behavior of deep-well waters throughout the past year, records too, that would give decided information regarding the future of deep water supplies throughout the State. No time nor means have been at hand for the continuation of paleontological studies bearing upon the upper Eocene and later formations. Too much stress cannot be laid on this point, for of all States, Louisiana is the one whose stratigraphy is to be worked out mainly by extensive paleontological investigations. Louisiana is in the very axis of the Mississippi Embayment region. Its formations have suffered frequent, extensive and local orogenic movements. Erosion, too, has played havoc with its fresh-water, marsh, and sea deposits whenever they have been raised above tide.

The southern portion of the State especially is extremely difficult to interpret, for over the irregular beds below, lies a smooth, regularly Gulf-ward sloping deposit giving an air of such simplicity of structure that layman and geologist alike have often held absolutely erroneous ideas regarding the stratigraphy of the whole region. It is then with extreme regret that we know of records being but partially kept, and then lost, from wells that should and would be of great value to all humanity if properly studied by competent paleontologists. We are frequently told that "the company that put the well down has the record complete." We examine it and find not the important things (fossils) preserved, but bottles full of clean washed sands and chunks of clay and sometimes pebbles, materials that may be encountered in almost any Cenozoic formation

It is sincerely to be hoped that now while records can be had, that the State Legislature will make liberal appropriations for their collection, interpretation, and correlation with the surface geology of the State as now being worked out by the Geological Survey.

SPECIAL REPORT
No. I

THE GEOLOGY OF THE MISSISSIPPI EMBAYMENT

WITH SPECIAL REFERENCE TO THE STATE OF LOUISIANA

BY

G. D. HARRIS

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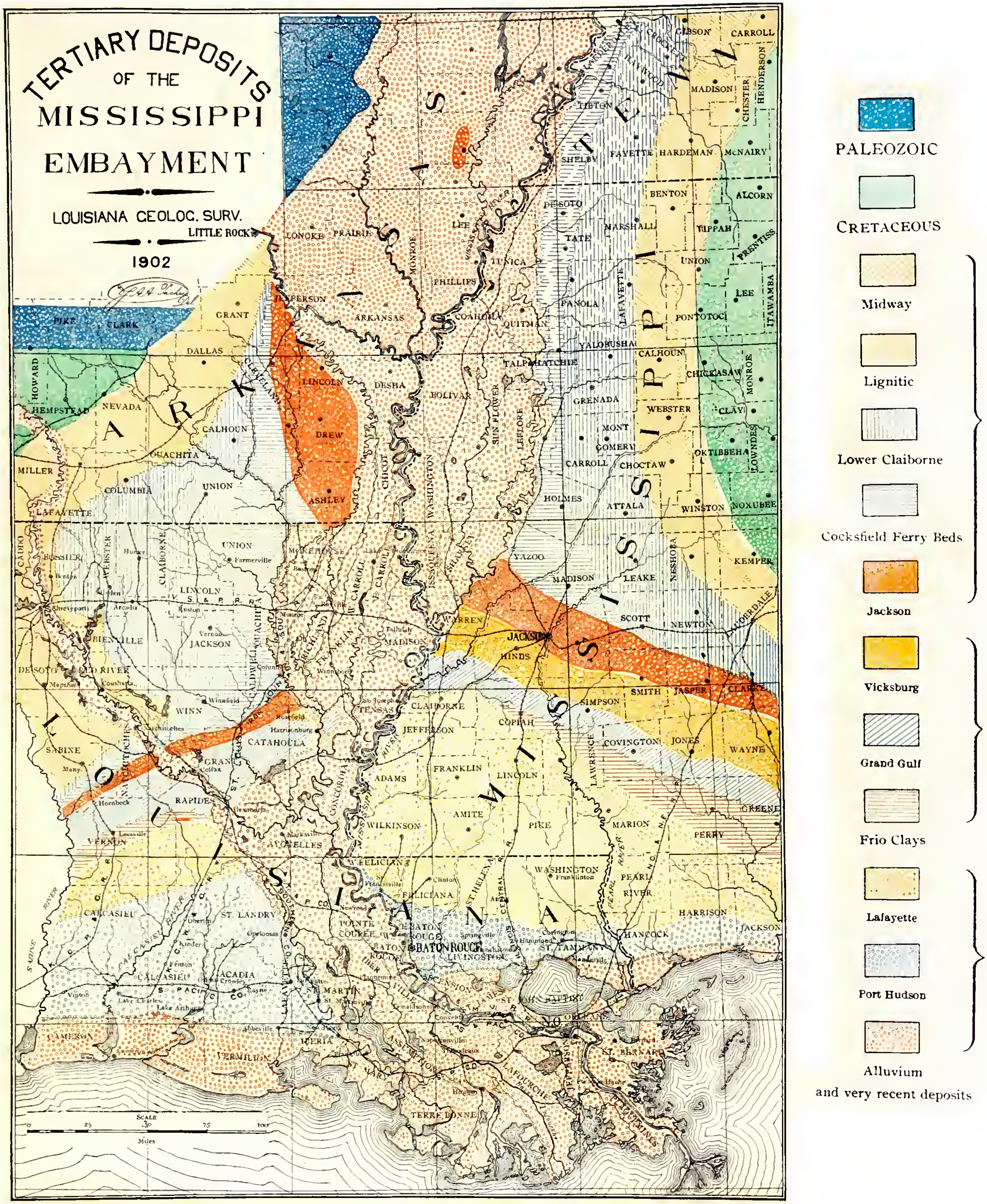
TERTIARY DEPOSITS
OF THE
MISSISSIPPI
EMBAYMENT
LOUISIANA GEOLOG. SURV.
1902
ARKANSAS
LOUISIANA
MISSISSIPPI
TENN
PALEOZOIC
CRETACEOUS
Midway
Lignitic
Lower Claiborne
Cocksfield Ferry Beds
Jackson
EOCENE
Vicksburg
Grand Gulf
Frio Clays
OLIGOCENE
Lafayette
Port Hudson
Alluvium
and very recent deposits
PLEISTOCENE
SCALE
Miles

THE GEOLOGY OF THE MISSISSIPPI EMBAYMENT

INTRODUCTORY REMARKS

Louisiana is situated in the lower Mississippi valley. The great river that winds its way through this valley, from the mouth of the Ohio, is flowing through a shallow, broad trough of comparatively modern origin. Not long ago, as time is reckoned in geology, southern Georgia and Alabama, nearly all of Mississippi, western Tennessee, southeast Missouri, the southeast half of Arkansas, all of Louisiana and southeast Texas, were covered with a northern extension of the Gulf of Mexico. This extension, especially the central portion, passing northward to Illinois, may be well termed the Mississippi Embayment.

It will be seen at once that whatever is said of the geology of Louisiana can be applied fairly well to a considerable portion of the Embayment area. We therefore take this opportunity of bringing together diverse observations by various authors relating to the whole area, in order that certain misapprehensions may be corrected, and that the geology of Louisiana may be seen in its true relationship to that of the surrounding states.

We need not go farther back or lower down in the geological series than the upper Cretaceous, in order to review the events that have been most important in Embayment Geology, at least so far as the State of Louisiana is concerned.

It may be noted here in passing that we are dealing exclusively with comparatively young or recent deposits when studying the geology of this region. The whole geological column (Fig. 1) is here inserted to show more clearly the meaning of this statement.

Explanation of the Map

The map herewith given, (Pl. I), shows the central or axial portion of this Embayment area. The different colors represent different geological formations laid down at different times as will be explained farther on. The extent of these formations northward represents fairly well the northern limit of the old bay or

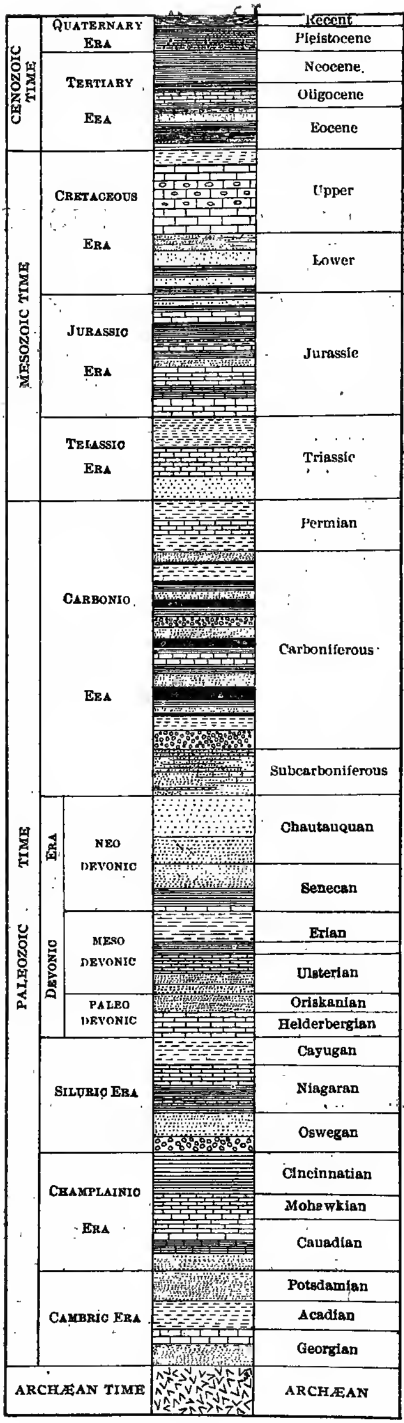

FIG. 1.—THE GEOLOGICAL COLUMN

RELIEF MODEL OF LOUISIANA WITH NORTH-SOUTH SECTION SHOWING THE STRATIGRAPHY OF THE STATE

sinus in which they were deposited; although doubtless small inlets, bays and tidal channels passed far beyond the borders as above indicated. During several different stages, there were, without doubt, many islands of varying size extending from southern Louisiana through the northern part of the State and eastern Texas.

CLOSE OF THE CRETACEOUS ERA

Orogenic movements and their results.—The close of the Cretaceous era was marked in this particular region by orogenic movements of no small magnitude. Cretaceous deposits were lifted above sea level in Tennessee and Mississippi and to the west in southern Arkansas, while in northeast Arkansas and farther northward the Cretaceous beds were lowered some distance below the Eocene tides. The point of no movement on the Tertiary-Paleozoic border line is, as we have stated before, not far southeast of Rockport, Ark., (Geol. Surv. Ark. Ann'l. Rept. 1892, Vol. 2, p. 184).

In Louisiana, however, we have reason to believe that the raising and depression of the Cretaceous beds was of a much more violent nature, that folds and faults were numerous and on a large scale, and that a great irregularity of surface features characterized the newly formed rocks.*

Present condition of Cretaceous rocks in the Embayment region.—We are not prepared to say just how much of the great disturbance these Cretaceous rocks show, was effected in Cretaceous time or just at its close. But we can scarcely conceive of small and slender, more or less isolated domes or peaks of Cretaceous material being commenced and completely formed after thick beds of Eocene deposits had been laid down on the Cretaceous floor.

The present condition of affairs for perhaps 1000 ft. beneath the surface in Louisiana, is shown on an exaggerated scale along the north-south section line across the State, Plate II. The Cretaceous outcrops have been discussed at length in our Report of 1899. Additional details may be found in Special Paper No. 2 accompanying this report styled "The Salines of North Louisiana," by Mr. Veatch.

* The same remarks apply equally well to southeast Texas.

Fig. 2 is a generalized section farther north, and in an east-west direction, extending from Bolivar, Tennessee, to Cabot, Arkansas. The Cretaceous, having been identified at both extremities, doubtless continues beneath the Embayment area as suggested by the diagram.

Erosion.—To what extent this whole region was eroded between the close of the Cretaceous and the beginning of the Tertiary we are not prepared to say. That the lowest Eocene beds have a totally different fauna from the Cretaceous and often lie uncomformably upon the latter, we have already shown in Bulletins of American Paleontology, No. 4.

In Louisiana, at the Winnfield "Marble Quarry," the fossiliferous lower Claiborne beds lie somewhat tilted upon the flanks of the Cretaceous uplifts. The exact relation of the other Cretaceous beds to the surrounding Eocene is not well shown. In Texas, however, Lignitic beds are represented as surrounding the Cretaceous outliers. The Salines in the vicinity of Sabinetown come up through the Lignitic deposits.

The Bayou Chicot limestone is surrounded by Quaternary deposits, and likewise the Saline elevations along the coast.

THE EOCENE SERIES

MIDWAY STAGE

Conditions of deposition.—The depression that had been slowly going on throughout the northern portion of the Embayment area during later Cretaceous times was continued, and seemingly reached its lowest stage in the earliest Tertiary. That area represented on the map between the

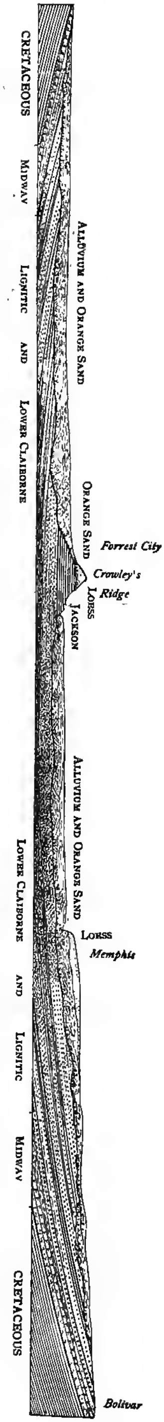

FIG. 2.—SECTION ACROSS THE MISSISSIPPI EMBAYMENT AREA FROM CRETACEOUS OUTCROPS AT BOLIVAR, TENN. TO CRETACEOUS BEDS AT CABOT, ARK.

Cretaceous outcrops of Arkansas and Mississippi constituted one broad arm of the Gulf, dotted here and there, over what is now known as Louisiana and southern Texas, by small Cretaceous islands and shoals.

Northern limits.—In this period it would seem that the waters of the Gulf extended considerably farther to the north than they did during the period that had just come to a close. We have already called attention to the fact that not far from Little Rock, Arkansas, there is a point at which the Cretaceous and Midway deposits are on about the same level; southward the Cretaceous rocks expand in a V-shaped area to the west and extend hypsometrically far above the Eocene border, while to the north of Little Rock the Eocene Midway beds cover the Cretaceous and lap over onto the Paleozoic formations.

Of the extension of these rocks in southeast Missouri we know little. Worthen has recorded the occurrences of lower Eocene deposits in Pulaski county, Illinois, and has identified from them a *Cucullæa* and *Turritella*. He also notes a bed of lignite at Caledonia. (Vol. 1., Geol. Surv. Ill. 1866, p. 44–46.) Loughridge has described at length the lower Eocene beds of western Kentucky in his volume on the Jackson Purchase Region. The fossils he mentions from near Paducah are not very satisfactory for determining to which division of the Eocene they ought to be referred. In Tennessee, however, we have studied in detail several fine Eocene exposures and have no doubt as to their stratigraphic position. (See Bull. Am. Pal. No. 4). Knowing, then, the behavior of the lower Eocene beds in Texas, Arkansas, Tennessee, Mississippi and Alabama, we are inclined to correlate the larger part of the Kentucky, Illinois and Missouri Eocene with the lowest or Midway stage. The peripheral, or what Dall has called the *perizonal* nature of these sediments in southern Illinois is evident from Worthen's description.

Type section.—It is in Alabama and Texas where the Midway beds are best exposed. They show generally at base bluish, micaceous clays, or clayey sands, and occasionally light, yellowish limestone ledges. These with the arenaceous layers above aggregate 100 feet. But one of the most noticeable beds is the limestone numbered 19 in Smith and Johnson's Pine-Barren section,

Bull. 43, U. S. Geol. Surv., 1887. This is usually replete with *Turritellæ* and contains oftentimes *Enclimatoceras ulrichi*. It is seemingly this bed that has a thickness of 40 feet in the vicinity of Tehuacana, Texas, whereas in Arkansas it scarcely ever exceeds twelve or fourteen feet. Following these limestone layers are usually beds of dark, or nearly black, selenitic clays, approximately 100 feet in thickness, though on the southeast margin of the Mississippi Embayment region, viz., at Fort Gaines, Ga., the conditions of deposition and the character of the deposits were totally different from those that obtained nearer the axis of the Embayment. In fact, a warm, clear water, off-shore condition prevailed, producing coralline life and limestone deposits.

Localities in Louisiana.—Such few little outcroppings of these as we have been able to find, namely at Rocky Springs Church and near King's salt works, indicate a near shore, shallow water condition, as might be expected from this location. *Ostrea crenulimarginata* forms practically the mass of the calcareous bed we have described from the Rocky Springs Church locality.

These small outcroppings are due of course, to local upheavals of a thousand feet or more. The beds of Midway age in Louisiana are mainly concealed by from 1000 to 3000 feet of subsequent deposition.

Fossils in Louisiana.—We have already shown on Plate 52 of our Report of 1899, all of the known, well preserved Midway species from Louisiana. The molluscan fauna of this stage, however, is known to embrace over 140 species from this Embayment region alone. These have been described and illustrated in Bull. of Am. Pal. No. 4, pp. 154, Pls. 1–15.

A large number of strikingly similar forms, evidently of practically the same Eocene horizon, have been described by Dr. C. A. White in Vol. 7, Arch. do. Mus. du Rio Jan. 1880, from the vicinity of Maria Farniha.

We especially call attention to such forms as *Harpa dechordata* *Calyptraphorus chelonites*, *Fasciolaria acutispira*, *Nautilus sowerbyanus*, *Gryphæa trachyophtera*, *Cucullæa hartii*, *Cardita morganiana*. Many of these are improperly named generically. The "*Harpa*" is a *Pseudoliva;* the "*Fasciolaria*" is a *Mazzalina;*

and the "*Nautilus*" is probably *Enclimatoceras*; but the specimens and figures bear out our remarks regarding the very close relationship of the Brazilian and Mississippi Embayment Midway species. Upon the whole, the Midway fauna is one of a moderately warm sea. It bears no relation whatever to the Cretaceous fauna just below it, but contains many types that endured even specifically throughout the Eocene and generically throughout the whole Tertiary.

THE LIGNITIC STAGE

Conditions of deposition.—During the latter part of the Midway age and throughout the lower Eocene ages the Embayment area was rapidly contracting, being filled in from the north by abundant clayey and sandy deposits. North of the Louisiana-Arkansas boundary line there is little indication of diverse conditions of deposition during the whole of lower and middle Eocene times. Dicotyledonous trees were abundant over the low islands and shores; palms and reeds occupied the swamps. The waters of the lagoons and swamps were brackish or fresh. Shells of the genera *Unio* and *Vivipara* have been found in these beds by the writer 3.3 miles north of El Dorado, Ark. (Ann. Rept. G. Surv. Ark., 1892, Vol. II, p. 140).

Such a continuous sameness in the conditions of deposition in beds of the axial region, of the Lignitic, Claiborne and Cocksfield stages renders all hopes of accurate differentiation of these stages in Arkansas, Missouri, Kentucky, Tennessee, as well as in certain locations in northern Louisiana and Mississippi quite out of the question. Fossil plants have not thus far proven an unerring guide for stratigraphic work in this region.

In going north from Ruston along the Railroad toward Chautauqua several unimportant sandy cuts are seen at varying intervals. But just before reaching Chautauqua station a deep cut exposes ferruginous, brittle, reddish layers, sand beds, and at the base of the cut, black, lignitic, sandy clays. Still farther to the north, ferruginous shelly red rock is very abundant in places. From such indurated layers we obtained a fair lower Claiborne fauna. These ferruginous rocks appear in abundance along the

railway for at least two miles. Out in the country in various directions these beds are well developed ; in fact they have been, doubtless, more or less instrumental in preserving the bold topography seen along the line of their local strike, from north of Chautauqua to Arcadia. Fossils have been collected from the Arcadia district by several geologists.

I am inclined to believe the lower Claiborne beds are rather thin in this region and that here and there Lignitic clays and sands come to the surface. Witness the lignitic clays between Dubach's mill and Middle Fork. The first deep cut going north from Dubach's, a distance of about two miles, shows at base 10 to 15 feet of bluish black, sandy, lignitic clays and above, 15 to 20 feet of light colored and red blotched sands, pebbles, and silicified wood. Another deep cut about two miles south of Middle Fork shows 20 feet of dark lignitic clay with fine sandy partings and occasional flat claystone concretions. Above, are 5 feet of mottled clays and sands ; and on top is a bed of red clayey sand. The flow of water at Dubach's mill is seemingly from these upper Lignitic sands. Owing however to the entire lack of fossils in these beds this correlation is mainly a conjecture.

Nowhere are these beds exhibited to better advantage in the upper Embayment area than along the Ouachita river in Arkansas. Such outcrops as occur above Camden have been referred to the Lignitic stage, while those below are doubtless the representatives of the lower Claiborne and Cocksfield beds of Louisiana. The materials composing these beds are mainly sand and clay, often very irregularly bedded and of various hues. A section at the old mine of the Camden Coal company is as follows, (N. E. ½, S. 12, 12S., 18W.):

1. Arenaceous material not well exposed.
2. Light pink clay .... 6 feet.
3. White sand .... 6 feet.
4. Bluish clay......................... 8 feet.
5. Lignite .... 6 feet.

Sand as a rule predominates. It is sometimes of a lighter color, more or less clayey, finely laminated, with thin yellow layers or streaks ; at other times it is blackish from carbonaceous matter and with very thin, pure, white sand, partings.

North of the Arkansas and west of the Mississippi there is, to our present knowledge, no definite information to be had regarding the distribution or characters of these beds.

In Kentucky, Mr. Loughridge has studied the Eocene with care and has referred some fossiliferous beds to the Lignite. From our knowledge of the distribution of the various Eocene faunas in the Embayment area, and from the characteristics of the rock containing them, we are inclined to put the fossils enumerated by Loughridge in the Midway. He sent his fossils to Heilprin, then in the Philadelphia Academy of Natural Sciences, who furnished the following identifications.

Nucula (probably *N. ovula*),
Leda protexta,
Leda costata,?
Mysia ungulina,
Turritella mortoni.

See Geol. Surv. viz. Jackson Purchase Region, 1888, p. 45.

The LaGrange group as restricted by Loughridge probably belongs to a lower or mid-Eocene stage.

We are not prepared to share Hilgard's opinion as to the probable occurrence of the "Flatwood Clays" in the Memphis boring. When we bear in mind the distance between Memphis and the continuation of some at least of the Flatwood clays in Tennessee where they are of the Midway stage; and when we bear in mind the depth at which Jackson fossils are found in the Helena wells, and their position at Forrest City, Ark., it seems far more probable that the lower 135 feet of the Memphis section are of middle or upper Eocene horizon.

The section shown on p. 8 is so constructed as to convey our present ideas regarding the stratigraphy of the area under discussion.

The east central part of the section represents the profile of the Memphis well as given by Hilgard, (H. E. Doc. 48 Cong. 1st Sess., Vol. 19, 1883–84, Miss. Riv. Comm. Rept., App'x. N., p. 483).

The profile about Forrest City is after Call; Ark. Geol. Surv., 1899, Vol. II, p. 217, while the western portion about Cabot is from personal observation of the author. See Ark. Geol. Surv.,

Ann'l. Rept. 1892, Vol. 2 pp. 11, 12, 25. This, it will be observed is practically a transverse section of the Mississippi Embayment in Lat. 35° N. According to a letter received under date of Apr. 3, 1902, the elevation of the mouth of the Memphis well No. 2 is approximately 288 feet Cairo datum, i. e. about 267 feet above tide. According to Hilgard's interpretation of the material passed through, the section is as follows:

Description of specimen	Depth'	Quartz
Loess	*Feet*	
Yellow silt, non-calcareous	1 to 47	Small, rounded and clear
Orange sand		
Orange yellow coarse sand......	47 to 55	Variegated with pebbles
Blue clay, yellow streaks.......	55.9 to 60.6	Small, clear, rounded
Yellow sand....................	60.6 to 63	Clear, mixed with chert and jasper
Coarse sand with gravel	63 to 93.9	Sharp and rounded Clear white, yellow and black
Orange colored sand............	93.9 to 99.8	Variegated
Orange sand, gravelly..........	99.8 to 117	"
Orange colored sand, lower part cemented into a conglomerate	117.5 to 132.2	"
Whitish clay...................	133.4 to 132.5	Fine and clear
Coarse, yellowish sand	132.5 to 133.4	Variegated
Whitish clay...................	133.4 to 134.1	"
Northern lignitic Tertiary		
Lagrange group		
Gritty clay, yellowish passing into bluish gray..............	139.3 to 150	Clear, small, rounded
Gray sand......................	150 to 154.5	Rounded and sharp Clear, some white and yellow
Flatwood group		
Stiff, blue clay	154 to 167	Very small, clear, round
Grayish sand...................	167 to 168.5	Clear and round
Stiff blue clay	168.5 to 275.1	Fine and clear

In Mississippi the Lignitic Eocene has not been defined with any greater degree of accuracy than in Arkansas. We are at present unable to state what portions of the northern part of Hilgard's "Northern lignitic" should be referred to the Lignitic proper, the lower Claiborne or the Cocksfield beds.

Type section.—Alabama, and Louisiana in part, seem to have been sufficiently far away from the apex of the Embayment to be occupied generally by salt water from the Gulf. The type section of the Lignitic stage is the Alabama section. The subdivisions with their respective thicknesses as given in Bull. No. 43, U. S. G. S., are:

Lignitic {
Hatchetigbee, 175 feet,
Woods bluff, 80-85 feet,
Bells l'd'g, 140 feet,
Nanafalia, 200 feet.

The typical Nanafalia beds are first met with in passing down the Tombigbee below Naheola, at Nanafalia bluff. But between these two localities the gradual transition from the darker Midway clays to the sandier Lignitic clays is noticeable. The section at Nanafalia Bluff is thus given by Smith and Johnson (op. cit.):

1. Greensand marl, highly fossiliferous, containing chiefly *Gryphæ thirsæ*, but holding also *Turritella mortoni* Con., *Flabellum*, and a few other fossils. This marl makes a tolerably firm rock, with a line of indurated, projecting bowlder like masses 12 or 18 inches thick, of nearly similar material along the whole length of the bluff and near the middle of the beds.... about 20 feet.

2. Dark blue, almost black laminated clay, devoid of fossils, but passing below gradually into a bluish marl........3 to 4 feet.

Bluish, greensand marl, with a few shells in the upper 3 or 4 feet, but more highly fossiliferous below. This bed contains a great variety of beautifully preserved and easily detached fossils. The fossils can be collected only during very low stages of the water..8 to 10 feet.

In going down the river below Nanafalia, a characteristic feature of the outcrop is the number of enormous concretions exhibited. These show clearly that the general dip is in a southerly direction, though reverse dips and unconformities are noticeable. Dark lignitic and grayish sands, more or less indurated, prevail for a number of miles. At Tuscohoma landing an extensive outcrop occurs; then again beds appear near the mouth of Bashi creek. Woods bluff, however, is the best section along this part of the river. It shows:

1.	Soil, sand with pebbles at base	40 feet
2.	Black clay, about	8 feet
3.	Line of concretions	4 inches
4.	Fossiliferous reddish and variegated clay	3-6 feet
5.	Black clay	10 feet
6.	Reddish fossiliferous sand	2 feet
7.	Fine gray fossiliferous sand	5 feet
8.	Concretions with large *Ostrea* var *sylværupis*	3 feet
	Water level.	

At Coffeeville a lower Claiborne deposit occurs, but several miles below at Hatchetigbee bluff uppermost Lignitic outcrops again. For perhaps 20 feet above water level, finely laminated dark clays predominate. Towards the lower end of the exposure or cliff there is an upstream dip which brings to day two or three layers of *Venericardia planicosta* often with valves united, almost as perfect as the shells strewn along the shores of modern seas. From 10 to 20 feet above water level one finds concretions, and, adhering to their lower surfaces are not a few well preserved shells. Ledges of light colored material, (buhrstone ?), occur here and there for 20 feet upwards but brownish clays predominate. High up in the latter one finds the most and best fossils.

Along the Alabama, south from the famous Matthew's landing outcrops of Midway clays, beds of dark sandy and lignitic clays give place to the Nanafalia marls at Gullette's landing, replete with *Ostrea thirsæ*. The best collecting ground does not appear, however, until Yellow bluff is reached. Gregg's landing some miles below is, perhaps, the best lower Lignitic exposure in the State for collecting purposes. Further downstream Bell's landing is seen on the left bank of the river. It is the last good exhibit of lower Lignitic beds on the Alabama. Four miles above Hamilton Bluff, as the river sweeps westward before its final southern deflection through the "Buhrstone" at Hamilton bluff, there is a low outcrop of Wood's bluff marls on the southern bank of the river.

The next good exposures of Lignitic beds occur at Ft. Gaines on the Chattahoochee river. Just below the long wooden bridge at this place the following section is found:

		Feet
1.	Red sandy clay and gravel (Pleistocene)	25
2.	Lignitic clay	20
3.	Fossiliferous sandstone ledge, *Ostrea compressirostra*	3
4.	Blue clay	6
5.	Alternating hard and soft layers	20
6.	Fossiliferous hard marl (seen in branch)	3
7.	Bluish sandy clay	30
8.	Sandy clay with concretions, *O.thisæ*	20
	Midway limestone.	

Farther east in Georgia we have discovered a Woods bluff Lignitic outcrop in a cut one mile east of Roberts' station. Shell fragments are seen in the blue marly sand for perhaps 200 yards. They are in some places 10 feet above the bed of the railroad. This is an extremely interesting outcrop, for it is by far the most easterly outcrop known of the Gulf Lignitic stage. This was discovered Dec. 25, 1901, by Mr. Pacheco and the writer.

West of the Embayment axis.—In Texas the Lignitic beds are well exposed along the Sabine as described in full in Mr. Veatch's Special Paper No. 3. Brazos river furnishes excellent outcrops of these beds, but, so far as known, no animal remains have been obtained from them. Calvert cliff, Robertson county, is a fine exposure. To the west or southwest it would seem that the Lignitic stage was poorly represented, at least at the surface.

In our report of 1899 we described the Lignitic outcrops in N. W. Louisiana, including those about Many, Marthasville, Coushatta, Mansfield and perhaps Shreveport. The majority of the fossil remains were figured in that report.

LOWER CLAIBORNE

Conditions of deposition.—We have already remarked that in the upper Embayment area conditions were quite similar from the beginning to the end of the Eocene. Toward the southern and broader portion of the area the sea was clearer and more suitable to animal life during the lower Claiborne age than it had been during the Lignitic. The Lignitic beds of east Georgia and west Texas were generally covered by Lower Claiborne deposits, while in Alabama and east Texas broad expanses of the latter are found, exceeded only by the still more-centrally located beds in the States of Mississippi and Louisiana.

Everything would seem to point, then, to a slight lowering of the southern Embayment sea bottom during Lower Claiborne times.

Type section.—In Mississippi, and especially in Alabama, the Lower Claiborne deposits have been divided in two groups. according to lithological characters. Smith and Johnson (Bull. U. S. G. S., No. 43), describe the lower portion under the name of "Buhrstone" and the upper under the name of "Claiborne." The Buhrstone they find developed to a thickness of at least 300 feet in central Alabama, though it is probably at least 100 feet thicker. It "consists of aluminious and silicious materials partly glauconitic, and in places interstratified with thin beds of greensand. The chief varieties of these rocks in the order of their relative abundance are the following:

"1. Gray, aluminous sandstone, often glauconitic, with numerous galls or concretions of pure whitish clay, and traversed throughout with streaks of yellowish hydrated oxide of iron. * * *

"2. Indurated, white clay, forming a rock, which is, however, quite light and easily broken * * *

"3. Hard, coarse-grained glauconitic sandstone * * *

"4. Hard, yellowish, silicious, or aluminious sandstone, streaked with a darker shade of yellow.

"5. A white silicious rock, almost quartzite."

At Hamilton Bluff on the Alabama, a fine expanse of the so-called Buhrstone is seen. But Smith has measured a more extensive section near McCarthy's ferry on the Tombigbee.

The upper division of what we have styled the lower Claiborne, is typically exposed at Lisbon and at the base of the bluff at Claiborne on the Alabama. It is, according to Smith and Johnson's measurements, about 120 feet in thickness, and consist, of clays of various colors, with a varying amount of calcareous matter.

The easternmost outcrops that can be regarded as belonging in any way to the Embayment area is one just discovered by the writer in central Georgia on the Van Buren place, about 10 miles east of Macon, Georgia. The Lower Claiborne character of the Shell bluff exposure on the Savannah we recognized while col-

lecting there as early as 1896; but it deserves only a mention here, since it belongs more properly with the Carolina province of this stage than to that of the Embayment now under consideration.

Throughout central Mississippi, northwest Louisiana, and southeastern Texas this stage is splendidly developed. The silicious Buhrstone character is not seen to any considerable extent west of the Mississippi. Sands, clays, marls and white, bowlder-like limestones, constitute the majority of the material in this section of the country.

Louisiana.—The Louisiana outcrops have been described at length in our report of 1899; little need be said here concerning them. One or two additional points, however, may be mentioned. They refer to the eastward extension of these beds along the Ouachita river. In the U. S. Engineer's office at Vicksburg are preserved samples of the material obtained from numerous borings made along the river for the purpose of determining the sites for the proposed dams and locks along this channel of commerce.

The borings that most interested us were those obtained from Rock Row shoals, about 13 miles above Monroe. The mouth of the boring is placed at 41.56 feet above mean Gulf level (H. E. D. No. 448, 57th Cong., I Sess., 1892. Find Report on Survey of Ouachita and Black Rivers, Arkansas and Louisiana, p. 131). At 17.29 A. T. very stiff clay, full of green sand, become darker upon exposure, is encountered. From here to the bottom of the well,—115.49, A. T. blue clays with shells, sand and rocklike, thin, hard layers were encountered. Well preserved, small shells, *Ringicula* and *Turratellæ*, were observed in the clay and greensand at about tide level. Other shells, *Mactra*, *Leda*, *Sphærella*, and *Tellina*, were observed in the specimens obtained from lower depths. One of the common Texas Lower Claiborne Pleurotomas was noted at a depth of about 135 feet. We have no hesitation in assigning the whole, from a depth of 124 A. T., to 157 feet below tide level to the Lower Claiborne Eocene.

At Monroe the various well sections near the river furnish Lower Claiborne fossils in abundance. *Distortio septemdentata V. planicosta*, *Turritellæ*, and *Pleurotomæ* of the Texas Lower

Claiborne fauna occur at depths of from 90 feet downwards (i. e. from 10 to 15 feet below tide). During the year 1900, Dr. Stubbs sent the writer a small paper box full of shells that he collected out of a well as it was being bored here. The species are: *Trigonarca pulchra*, *Veneracardia planicosta*, *Nucula magnifica*, *Corbula* sp., *Turritella* var. *nasuta ?* *Distortio septemdentata*, *Pseudoliva vetusta*, *Nassa texana*, *Latirus moorei*, *Natica arata*, *Levifusus trabeatus*, *Terebra houstonia*, *Calyptraphorus velatus*, *Marginella constrictoides*, *Volutilithes petrosus*, *Solarium alveatum*, *Pleurotoma nodocarinata*, *Clavilithes humerosus*. Veatch found an outcrop of this formation as described in his report on the Ouachita, in the bed of the river about on the section line between Sections 2 and 11, 3 E. 16 N.

These facts show clearly that although this formation is masked by later deposits in the region between Winnfield, Vernon and Ruston on the west and the Ouachita River on the east, it does extend in full force eastward to, and doubtless underneath the great alluvial plains of the Mississippi.

West of the Embayment axis.—By far the most systematic and extensive work done so far on the Lower Claiborne of Texas was that carried on under the former Geological Survey of the State. The publication by Kennedy in the Proceedings of the Philadelphia Academy of Natural Sciences for 1895, and the accompanying blue-print MS. map show with a fair degree of approximation the Lower Claiborne area in east Texas, though local and more minute investigations by Veatch have brought to light many minor points of error in Kennedy's work.

The Paleontology of the Lower Claiborne of Texas was reported upon in full to the Texas survey by the present writer, but the survey was discontinued before the work was published. It included nearly 400 type written pages and 30 large 8vo. plates. Some of the new species were described, however, in 1895, (Proc. Ac. Nat. Sci. Phila., 1895, pp. 45-88, pls. I-IX).

A recent publication by the U. S. Survey gives an attempt at correlating the Louisiana and Texas, though little new information is brought forward. See Bull. 184, pp. 40-48.

UPLAND PINEY WOODS NEAR WINNFIELD "MARBLE" QUARRY

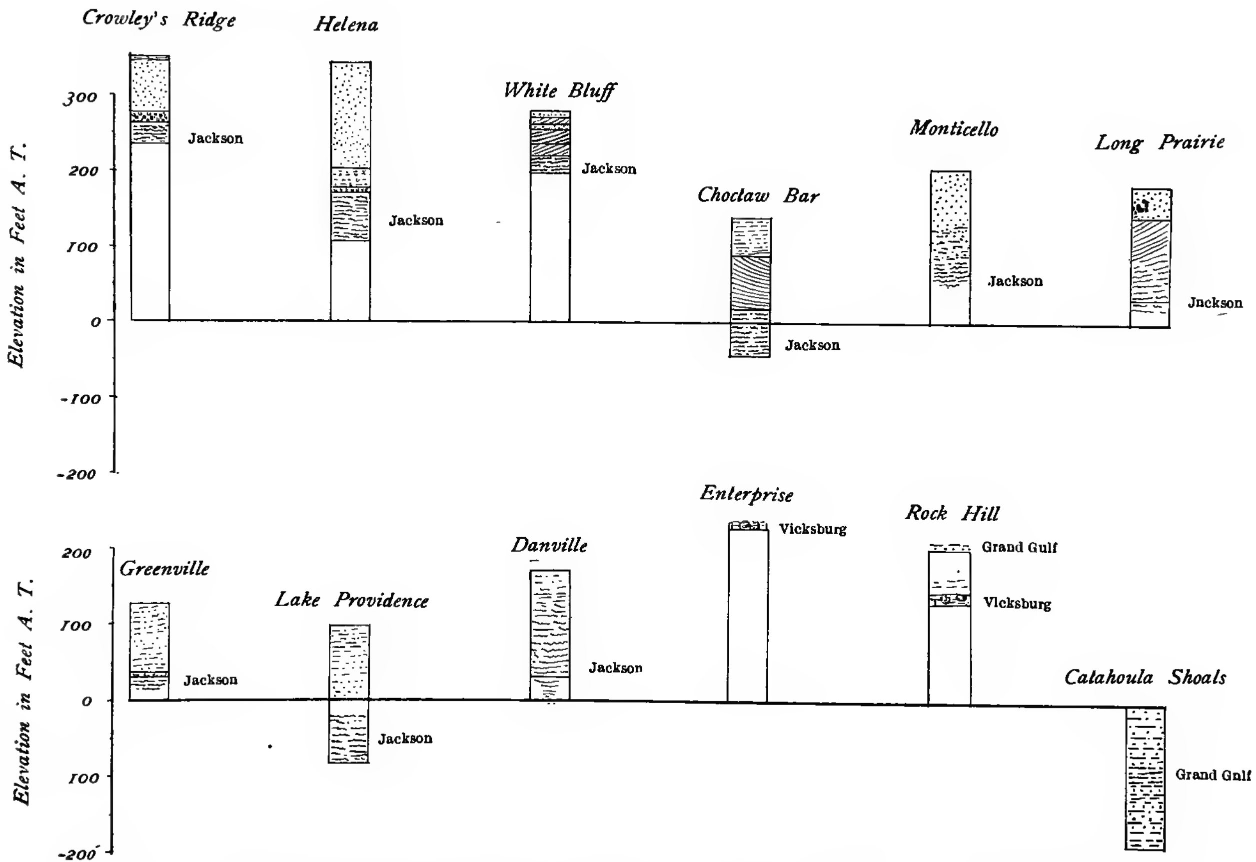

PLATE IV.—SECTION SHOWING THE RELATIVE ELEVATION A. T. OF JACKSON BEDS AS FOUND IN VARIOUS OUTCROPS AND WELLS IN ARKANSAS, MISSISSIPPI AND LOUISIANA

COCKSFIELD BEDS

Condition of deposition—We have already described the lagoon or swamp-like condition of the upper portion of the Embayment area during the lower portion of Eocene times. While the Cocksfield beds were being laid down, these conditions evidently prevailed over regions farther south, even central Louisiana and Mississippi. The result is, that over the marine Lower Claiborne beds of Louisiana come lignitic sands and clays, having a thickness of perhaps four or five hundred feet where well developed.

Type section.—These beds are well exposed along the cuts in the K. C. P. & G. R. R. between Florien and Christie's switch (Fig. 3) as well as the type locality on Red river, *i. e.* Cocksfield ferry, between St. Maurice and Montgomery. Perhaps the best place for observing them in deep cuts and extensive outcrops is along the Iron Mountain R. R. just southward from Columbia, Caldwell parish. Plate VI, opposite page 80 of our Report of 1899, shows one of these deep railroad cuts. The extensive sand beds exposed along the V. S. & P. R. R. east of Ruston we refer to this horizon. Likewise the lignite-bearing sands and clays on the Ouachita in Arkansas in southern Bradley, western Ashley and eastern Union counties; though this is necessarily more or less of a conjecture since the leaves, practically the only fossils contained, have not been carefully studied and differentiated from the flora of the Lignitic proper.

In Mississippi these beds presumably occupy the area between the silicious Claiborne area of Caroll and Atala counties and the Jackson to the southwest. They seem to represent the upper Claiborne of east Mississippi and Alabama. West of the Sabine these beds are represented by the lower portion of the "Yegua clays" of the Texas nomenclature. See special Report No. 3.

FIG. 3.—SECTION ALONG THE K. C. P. & G. R. R. THREE-FOURTHS MILE SOUTH OF FLORIEN, EAST SIDE OF THE TRACK; ABOUT 16 FT. IN DEPTH.

JACKSON STAGE

Conditions of deposition.—During this age the depression along the axis of the Embayment area had more than kept pace with the filling in by sedimentation, so that a large sheet of salt water spread northward as far as Crowley's Ridge, Arkansas, and presumably farther.

Northern limit.—At the time of writing my report on the Tertiary of Arkansas (1892), I felt strongly inclined to refer the fossiliferous beds at White bluff on the Arkansas river to the Jackson; yet, they had always been referred to the Claiborne and there seemed not enough positive evidence in favor of the Jackson affinities to entirely warrant the change. Since then some of the new, or supposedly new, species from White bluff have been found in abundance at Jackson, Mississippi, and at well developed Jackson beds throughout Louisiana and east Texas. The Red bluff beds upstream a few miles from White bluff seem to be of the same horizon: and although I have not visited Crowley's ridge personally, I feel quite confident from Call's description of the beds and associated fossils, together with his correlations, that all should be placed in one and the same group. Accordingly the map of the Embayment area as herewith published shows the Jackson for the first time with its most probable northern distribution. Here again we would refer the reader to our generalized section across the Mississippi valley, from Memphis to Cabot, Fig. 2, p. 8. The moderate southward slope of the Jackson outcrops throughout the Embayment area is shown by the series of sections herewith given, Plate IV.

It should be mentioned in this place that we have had access to Hilgard's type specimens from Helena and Choctaw bar* and

* HELENA (Boring No. 2): *Dentalium* (very nearly smooth, but with traces of longitudinal striation); *Volutilithes petrosus* (fragments); *Corbula wailesiana*, *Corbula* sp.; *Phos hilli* var.; *Pseudoliva vetusta*; *Pleurotoma denticula*; *Actæon*; *Natica*.

CHOCTAW BAR (Boring No. 1): *Venericardia planicosta*; *Dentaluim* (as at Helena); *Cadulus*; *Pleurotoma*; *Actæon*, *Turritella* (very small, unicarinate at base), *Phos hilli*.

(Boring No. 2): *Phos hilli* (labelled "*Buccinum*" and "*Fusus mag-*

have found that his specific determinations of molluscan fossils is not of the most sactisfactory kind. The species are the same in general as at White bluff, Arkansas; hence, as shown above, of Jackson age. (See Hilgard's report: H. E. D., 48 Cong. 1st Sess., 1883–84, vol. 19, Appendix N, pp. 479–497). We believe there is no other place in the country where the Jackson beds are so well exposed or so well developed as along the Ouachita river, and we have been to considerable pains to secure full information regarding this region. The stratigraphy of the Jackson beds above Danville has been worked out by Mr. Veatch. (See Special report No. 4).

At Danville and a few miles to the south, these beds are finely developed, showing a proven thickness of 80 feet above an approximate mean river level, and a probable thickness of 150 feet above the same datum plane. Vicksburg beds appear back of Enterprise, P. O., at a height of 231 feet A. T., while Jackson fossils were traced in the same vicinity to a height of 116* feet, A. T.

About 3 miles south of Danville, and nearly as far from the river, there is an eminence capped with Grand Gulf sandstone at an elevation of 203* feet A. T. The Vicksburg marls and calcareous bowlders are exposed in the stream valleys nearby at an elevation of 130 to 143 feet A. T. These beds, therefore, show a southern dip of about 50 feet per mile, and we are

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nocostatus"); *Natica* (small); *Pleuratoma infans; Levifesus trabeatus; Cancellaria; Corbula* small, probably *wailesiana*, *Turritella clevelandia; Venericardia rotunda; Volutilithes petrosus; Actæon; Calyptraphorus velatus* (tip of, labelled "*Nassa cancellata*").

Boring No. 4): *Turritella* (small, sharply bi-carinate); *Phos hilli; Oliva* cf. *gracilis* Lea; *Natica* (small); *Venericardia parva; Corbula wailesiana.*

(Boring No. 5): *Pseudoliva vetusta; Natica*, (small) *Pleurotoma denticula; Venericardia planicosta; Turritella*, (tip bi-carinate); *Volutilithes petrosus; Corbula wailesiana; Actæon.*

LAKE PROVIDENCE (Boring No. 3): *Leda multilineata* (radial marking on anterior only); *Leda;* depth 135 feet. *Venericardia planicosta* and *V. rotunda;* depth, 137 feet.

*These elevations were determined by running a spirit level line to these various points from B. M. B. Ouachita River Survey, in lot N. W. of Danville, P. O. Top of gas pipe given as 24.5363 meters C. D.

inclined to believe that the Jackson beds share this dip with the higher or Vicksburg beds.

Section along the K. C. P. and G. R. R.—Another section of the Jackson, studied more thoroughly this year than heretofore is that along the railway just mentioned, in western Louisiana. About 1½ mile north of Christie's switch, Jackson beds appear capped, as were the Cocksfield beds, by the so-called Orange Sand. They consist here of light colored clays, and contain traces of fossils. *Volutilithis petrosus* and *Nassa* are the most abundant forms.

South of the switch one-half mile, a more extensive exposure of fossiliferous Jackson clays is found. The upper surface shows extreme irregularities of erosion before the deposition of the superincumbent Quaternary material.

The cut passed through about one-third mile before reaching an old saw-mill site is remarkable in many ways. The erosion that washed out the great channels in the upper surface of the Jackson clays, left sometimes very steep and over-hanging banks; so steep, in fact, that after the lower part of one channel had been filled with sand and gravel, the upper part of the over-hanging bank pressed down upon the refilled material. At first sight it seems as though the gravel actually passes beneath the clays, but this is doubtless not so. The gravel has been re-channeled and re-filled in places with coarser gravel and sand. See Fig. 4.

In the cut at the old mill there occur first, finely laminated clayey sands. In the middle of the exposure there are very lignitic clays. These give way in the southern part of the cut to dark clays which turn reddish on exposure. About 300 yards to the south there appears a high hill on the right or southwest where but 60 feet above the track Grand Gulf sandstone crops out very conspicuously.

FIG. 4.—CUT SHOWING JACKSON CLAYS WITH CHANNEL FILLED WITH ORANGE SAND, DEPTH ABOUT 10 FEET

East of the Embayment axis.—In Mississippi the Jackson beds are well developed as the name Jackson would naturally imply, but they thin out rapidly eastward and are represented in the Claiborne section by only a few feet of marly limestone, the base of the so-called "White Limestone." We have personally collected from these beds at Claiborne *Mitra millingtoni* and a few other such characteristic species.

West of the Embayment axis.—In Texas, in fact in all regions west of the Red river, the members of this survey have discovered and traced the course of the Jackson. While employed by the Texas survey, the writer received a few samples of gray sandstone from a "cutting on the Houston E. & W. Tex. R. R. 4 miles north of Corrigan, Polk Co.;" but no casts were preserved of shells other than might well belong to Claiborne species and the beds were therefore classed under that heading. During the past winter the vicinity was studied by Mr. Veatch and a number of fairly distinct casts were shipped to the writer, then at Calhoun, La. The Jackson aspect of these fossils was at once evident, and Mr. Veatch informs us that the stratigraphy is in harmony with this conclusion. The large Fulgur-like *Levifusus branneri* and *Mazzalina* var. *oweni*, in considerable abundance, speak clearly of the age of the material enclosing them.

While at Sour lake, Texas, the writer found among the debris washed out from near the bottom of a 1500 foot well a fine Jackson fauna, preserved evidently in a blue selenitic marl. The well referred to is located just back of the P. O. close by one of but 900 feet in depth. Along with such fossils as *Volutilithes petrosus*, *Venericardia rotunda*, and fragments of *Pecten* and *Pinna*, we observed *Alveinus minutus Eucheilodon creno-carinata*, *Corbula wailesiana*, and several undescribed Jackson species.

The important bearing of these facts on the stratigraphy of this portion of the state when considered in connection with the flowing well but four miles distant, down to a depth of 1915 with no indications of lower Tertiary beds or fauna, is at once apparent. This point will be referred to later on.

OLIGOCENE SERIES

VICKSBURG STAGE

Conditions of deposition.—The great geographic changes that took place between Eocene and Oligocene times in the Mississippi Embayment are clearly shown on the accompanying map. (Plate I.) There was no longer a narrow bay extending from the Gulf of Mexico northwards towards, perhaps even to, the mouth of the Ohio. There was only a gentle curve in that direction as the map clearly shows. There would seem to be moreover, no doubt as to the former continuity of Oligocene beds from where they are represented in Louisiana across the Mississippi valley to the more extensive outcrops in Mississippi. What at this period became of the turbid waters of the Mississippi river it is difficult to imagine.

Distribution in Louisiana.—The Vicksburg beds of Louisiana are confined to the region about Rosefield P. O., or more definitely, from a point about ½ mile west of Enterprise P. O. on the Ouachita, to perhaps 5 miles southwest of Rosefield. Just south of Rosefield the hills are capped by Grand Gulf material, but the steep and deep valleys on all sides show Vicksburg marls, limestone boulders, and often Vicksburg fossils. Some locations have been already specified in our Report of 1899. Heretofore, however, the Vicksburg fossils of Louisiana have come apparently from one and the same horizon. Bluish or yellowish marls, with light colored limestone boulders of various size usually indicate the propinquity of good collecting grounds. Now we are able to state that there are at least two fossil-bearing horizons between 40 and 50 feet apart. They are both seen in the vicinity of Sone's store southeast of Rosefield P. O. In a hollow south of his house about ⅓ mile, there is a seam of bluish clay literally packed with small bivalve shells of one species, viz : *Corbula alta* Con. The usual Vicksburg fossiliferous bed is seen a few yards southeast of the same house, in narrow, deep, storm-carved channels. In several places hereabouts a seam of "coal" is found, occupying a stratigraphic position about equivalent to the *Corbula* bed, though presumably just a little below it as is seen below in the Vicksburg section. To the southeast

VICKSBURG BEDS, MINT SPRING BAYOU, VICKSBURG, MISS.

of Rosefield, some four or five miles, fossils are reported in the deep ravines that occur just below the Grand Gulf sandstone horizon.

Typically developed in Mississippi.—One of the best developments and earliest studied sections of this formation is at Vicksburg, Mississippi. The military road leading north from the town is flanked landwards by an abrupt slope, showing in places thick, light-colored, limestone layers, at others, light marls. Mint spring bayou at the entrance of the U. S. cemetery exposes along its course an excellent section. The photograph herewith reproduced, (Plate V)*, shows a rather heavy bedded limestone above, with very fossiliferous clays beneath. Still higher, at Mint spring, other clays are found, likewise replete with another group of molluscan species, mostly Arcas. These strata come under No. 5 of Hilgard's section given below:

No. 5.—Alternating strata, 1 to 6 feet thick, of limestone and marl, containing the Vicksburg fossils, and some brands of non-effervescent, gray sand and clay: 60 to 65 feet thick.

No. 4.—Black, lignitic clay, and gray sand, with *Ostrea gigantea*, *Corbula alta*, *Natica mississippiensis*, *Cytherea sabrina*, *Madrepora mis.*: 5 feet.

No. 3.—Gray or black lignitic clays or sand, with iron pyrites; exuding salts and sulphuretted hydrogen: 25 feet.

No. 2.—Solid limestone lignite, with whitish cleavage planes: 3 feet.

No. 1.—White limestone of the Jackson group.

The dip of the strata here is quite slight, perhaps on an average scarcely 10 feet to the mile in a southerly direction.

The whole thickness would seem to scarcely exceed 100 feet at this type locality.

Farther east, in southern Alabama, the *Orbitoides* bearing Vicksburg beds are given a thickness of 140 feet by Smith and Johnson.

Great development in Georgia.—In Georgia they cover a vast portion of the State as pointed out by the writer in 1895.† Their

* Borrowed from Bull. Amer. Paleont. No. 15.

† See American Geology, Vol. 18, p. 236, 1896.
See also Bull. Am. Pal. No. 15, p. 67 et seq., 1902.

northern boundary passes northeastward from near Ft. Gaines, Ga., to near Macon. They simply mask all Cretaceous and Eocene deposits in this portion of the State. Their thickness, however, can not at present be estimated with anything like a fair degree of accuracy.

GRAND GULF STAGE

Frio sub-stage.—If we adopt the Texan nomenclature for the upper, green, calcareous clays of the Grand Gulf beds, the whole stage would be thus divided. 1, Grand Gulf beds proper: light colored sands, clays and sandstone layers at base. 2, Frio clays: light greenish clays, sand and light calcareous marls replete with white concretions of very irregular forms of various sizes. Occasional typical "Red river clay" beds are reported from the Frio horizon.

Both the usual phases of this stage are splendidly developed along the K. C. P. & G. R. R. from Christie's switch to five miles south of Leesville. The sandstone ledges are fully exposed about Harrisonburg and Sicily Island.

Condition of deposition.—From Alabama to near Rosefield, Louisiana, the northern shoreline of the Grand Gulf sea seems to have agreed in direction fairly well with that of Vicksburg time. But farther west, doubtless the Vicksburg shore line took an abrupt southerly bend, whereas the Grand Gulf's continued in its general west-south-west direction. Certainly great origraphic changes took place between the time when the Vicksburg beds were deposited and the beginning of Grand Gulf deposition. The Vicksburg beds show an off-shore, clear-water condition for the most part; the Grand Gulf, the reverse; being we believe, in many places deposited in shallow fresh water basins. The astounding dearth of fossil remains, remarked upon by Hilgard and others so often and with such emphasis is, it seems to us, accounted for mainly by the fact that the calcareous concretions so abundant in many portions of the Frio clays, are not derived from the tests of mollusca as was formerly supposed, but have been extracted from fresh waters by certain kinds of water vegetation.*

* Journal of Geology, vol. 9, 502 and 506; 1901; C. A. Davis.

BLUFF AT GRAND GULF, MISS.

Stratigraphy along the Ouachita.—Three miles south of Danville at Rock Hill, as has already been stated, the base of the Grand Gulf sandstone layers is 203 feet A. T. The fossiliferous Vicksburg beds in little ravines close by are from 60 to 70 feet below the sandstone layers, the intervening space is covered. Yet in the Harrisburg road perhaps two miles further south, thick sand beds were observed beneath the indurated ledges. These we would naturally place in the Grand Gulf stage. Ten miles southeast of Rock Hill, at Catahoula shoals, borings made by the U. S. Engineers indicate the presence of hard Grand Gulf layers to a depth of 128 feet A. T. In this direction therefore, nearly due southeast, the dip is about 31 feet per mile. If, however, we take the approximate elevation of the lower beds of the Grand Gulf just across the river from Colfax as 110 feet, and note the distances and directions from each of these points and solve graphically for direction and amount of dip, we find the true dip to be south 26° east at the rate of 34 feet per mile. This is interesting as proving with fair certainty that the basal sandstones of this formation do not extend much below water level at Stafford's landing. In other words, Bœuf river joins the Ouachita along the northern outcropping of the bottom hard ledges of the Grand Gulf sandstone. Rather strong local dips are to be seen in the sandstone ledges in the bluff at Harrisonburg. If, however, they do not affect the general dip as discussed above, the more or less arenaceous and indurated layers of the Grand Gulf, have a vertical range of about 250 feet and the total thickness where the basal sands are included is no less than 300 feet. The Frio clays, if present at all in this region, must be some distance to the south of the outcroppings of the harder Grand Gulf beds, and hence are covered by the recent alluvium.

Fossils.—In the southwest quarter of section 7, 10 N., 5 E., the gray sandstones and clays of the Grand Gulf alternate, near the summit of several eminences in this vicinity, with light sea-green finely laminated clays. These clays upon exposure become almost pure white, and hence the name of the locality, Chalk hills. We were fortunate to secure from these lighter clays not only a good quantity of well-preserved, dicotyledonous

leaves, but also several casts of one or two species of *Unio* and *Anodon*. We are confident that if time and means for the work were at hand, a most interesting chapter could be written on the proofs of the freshwater origin of a large share of the Grand Gulf sands and Frio clays. A careful study of the microscopic features of all these rocks is what is now most needed in order to bring out in more detail their condition of deposition. However, the mollusks and the leaves will soon be published, though the manuscript could not be prepared in time for the present report.

At the forks of the quarry switch east of Christie's (K. C. P. & G. R. R.), we found a section (Fig. 5), showing cross-bedded sands with chunks and balls of brittle clay and more or less Lignitic clay. The unconformity shown by the various layers is most remarkable. A few fragmentary casts of small bivalves were found in a shelly layer perhaps half way from the forks of the switch aforementioned to the old quarry. These were found mainly on the northwest side of the track near a highway crossing. Just to the southwest is a cut showing flow-and-plunge structure in semi-indurated sands. Stratigraphically and lithologically these remains might well be of Grand Gulf age. But when we consider that the base of the so-called Grand Gulf in Texas contains casts of Jackson fossils, we are inclined to think that these few bivalves are the last survivors of the Jackson age.

Well sections.—From rock specimens seen at Moresi Brothers' foundry in Jeanerette, and from what could be seen of the well being sunk at Anse-la-Butte with the Moresi outfit, we are warranted in stating that from 800 to 1500 feet in depth the drill was continually in Grand Gulf and Frio material. The same light clays, often of a greenish hue, and sands predominated, that can be

FIG. 5.—QUARRY SWITCH, NEW FORKS: SHOWING EXTREME UNCONFORMABILITY BETWEEN EOCENE AND OLIGOCENE DEPOSITS.

seen in surface outcroppings from Leesville to Hornbeck. Personally we have never seen at a surface outcrop the sticky red compact clay that is said to have been passed through in the well between the depth of 1415 to 1450 feet. Yet Mr. Hill, who had general oversight of the work, informs us that a similar red bed was passed through under similar circumstances in a well 15 miles south of Alice, Texas. Again, in a letter recently forwarded to the Survey, mention is incidentally made of the surface outcropping of a red clay bed in the vicinity of Leesville, La. Also, in the Spring Hill well, at a depth of several hundred feet (exact depth not given), a precisely similar formation was encountered.

The so-called Spring Hill well is located about 9 miles in a southeast direction from Oberlin, La. Besides the interesting feature just mentioned, this well, according to Mr. J. T. Jackson (driller), at a depth of about 1450 passed through a very hard ledge of light sandstone. The auger employed certainly showed hard usage. At a depth of about 1500 feet, the drillings being washed up at the time of our visit (in early March), consisted of clear quartz sand with greenish flakes of clay. No shells had been found in any of the washings. According to the same driller an abundance of gravel was found at a depth of 1200 feet. This, if not an error, would imply a dip of at least 40 feet to the mile for these Lafayette beds or the upper surface of the Grand Gulf from their exposures southwest of Alexandria, southward to this well.

There is a strong probability that the well styled "Southern No. 1" reached a Grand Gulf horizon at 2600 feet. The wells in the same general vicinity, *i. e.* a mile or so north or south of Evangeline, seem to show the same uppermost faunal phase as was obtained at similar depths (1500–1800 ft.), in the deep well at Galveston. Again the material obtained from a depth of 2600 feet has a decidedly fresh-water, river mud appearance.

I do not think the Watkins well southeast of Lake Charles, 2400 deep, reaches the Grand Gulf. However, in Texas, Tertiary beds have certainly been found in a well at Sour Lake, as described above; even near Spindletop the evidence of Grand Gulf Tertiary in some of the wells is quite satisfactory.

The Treadaway well, down 1850 feet, Mar. 11, 1902, showed gravel and recent appearing forms down to that depth. A well about one-fourth mile to the east, temporarily abandoned (at a depth of 2015 feet), however, showed mottled marls and greenish sandy clays referable with little doubt to the Grand Gulf horizon.

NEOCENE SERIES

Well records.—No marine Neocene Tertiary, so far as we are aware, comes to the surface in Louisiana or Texas. Their position in the substructure of Louisiana can best be understood by examining the sectioned model, Plate II, of this report. They have been completely blanketed by more recent deposits. Our knowledge regarding them is scanty, owing to the lack of interest that drillers manifest in keeping fossil specimens from each and every well put down.

The Crowley well, near Evangeline, is interesting from the fact that a depth of approximately 2000 feet many specimens of *Rangia johnsoni* were found, along with fragments of *Mytilus* and *Ostrea.* Praire Mamou well, about 2200 feet deep, shows the same *Rangia johnsoni* along with the Galveston well variety of *R. cuneata.* These show fairly conclusively that a western construction of the Pascagoula Miocene beds are here encountered. "Southern No. 2" shows at 1800 feet the same uppermost Tertiary aspect of fossil remains that was found in the Galveston well at a similar depth. The Watkins well near Lake Charles seems to reach at 2400 feet approximately the same horizon that is found east of Jenning's at a depth of less than 1800 feet.

CLOSE OF TERTIARY AND BEGINNING OF QUATERNARY

LAFAYETTE STAGE

Occurrence in Louisiana.—The disconnected areas of gravelly material in the Embayment region north of the Oligocene outcrops, belong perhaps to several different geological ages; but south of the same outcrops these coarse materials seem to con-

stitute one extensive, unbroken formation, though varying greatly in kinds of material and doubtless considerably in actual time of deposition.

It has been my belief for several years that whenever the shingle of an old shore has been preserved, there will be found "Orange sand," be the age of such littoral beds Mesozoic or Cenozoic; that, if the shore line is pushed out at intervals, by the raising of the land or the depression of the sea, then erosion sets in with renewed vigor and carries the greater part, or all it may be, of the old littoral deposits to lower localities, often into the sea. If the relative level of land and sea remains for a long time practically unaltered, then the sea may transform a gently

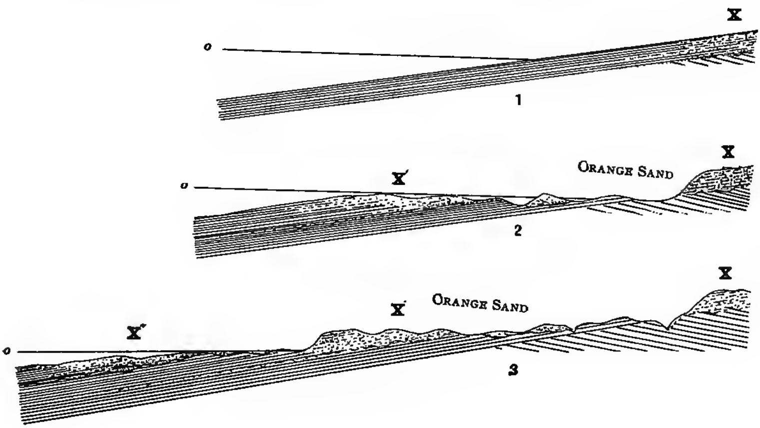

FIG. 6.—SHOWING PROBABLE ORIGIN OF "ORANGE SAND"

sloping, elevated sea-bottom plane to a shore of wave-formed cliffs with but moderate depth in the bordering waters. Such action would often account for the occurrence of gravel located on plateaux, with beds of the next older stage, consisting of firmer materials, lying unconformably below.

A graphic representation of the ideas we would express is given herewith in Fig. 6. Coarse littoral material, orange sand, we will say, is deposited in the first place on an irregular surface of older rocks. The coarser material has been deposited near the shore, the finer farther seaward. This material is subsequently

elevated and appears at X. Erosion and wave action set in and the result is that part of the X material is transported and forms X'. Some remains at X as plateau gravel. These processes may be repeated many times and the result will be that when the country inland has been dissected even moderately, the gravel will appear (a) as the capping of plateaux, or (b) as gravel trains along the water courses either of to-day, or those of periods subsequent to the primal elevation of the region above sea level.

We refer the reader to our Report of 1899 for an account of the gravel beds north of the Grand Gulf outcrops in Louisiana. Those in Arkansas are discussed in several volumes of the annual reports of the Arkansas Geological Survey, especially vol. 2 of the years 1888, 1889, and 1892. Special interest in this report centers in the Lafayette beds to the south of the Grand Gulf outcrops, inasmuch as from these outcrops southward they are continuous, and play an important rôle in the economics of southwest Louisiana.

At Harrisburg these beds are over 150 feet A. T.; near Neame, over 275 feet A. T. At Sulphur, in southwest Louisiana, they extend to a depth of over 400 feet below tide; just east of Morgan City, over 500 feet below the same datum plane. East of the Mississippi river their behavior is well shown in the accompanying section, Fig. 7.

For want of carefully kept records and samples, and lack of organic remains, the depth to which the so-called Lafayette beds extend can not be given with accuracy. The light bluish clay and sand layers penetrated between depths of 500 and 2500 feet and containing few and from miocene to recent organic remains, seem to be most probably the seaward representations of the coarse gravelly material as it flanks the Grand Gulf or Frio beds farther north. Such gravels, then, may be properly discussed under the head of upper "Tertiary deposits," whereas the gravel encountered in the wells is most certainly Quaternary. *

The drawing of hard and fast limes separating the so-called

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* The fact that this littoral material, of identical appearance, (usually referred to by one name), belongs to so many different ages, renders its discussion, in a report chronologically arranged, necessarily somewhat awkward.

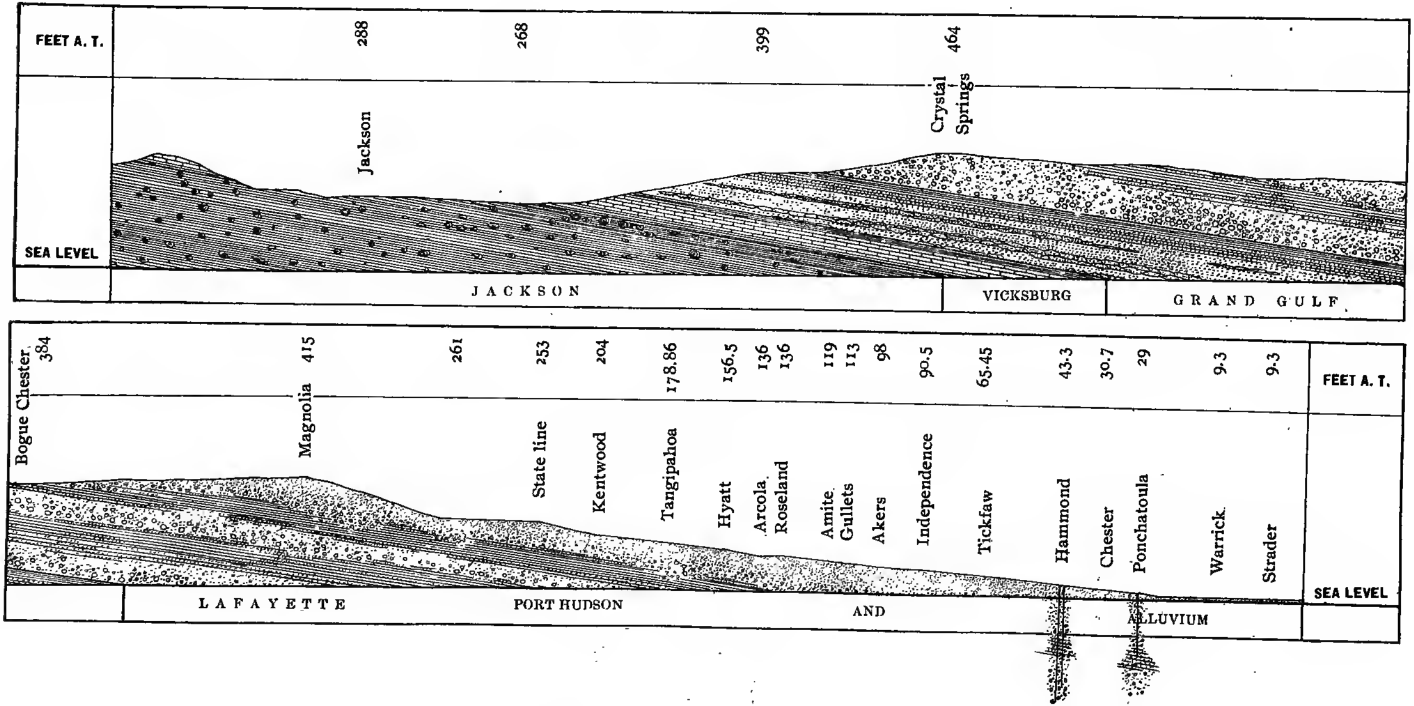

FIG. 7.—SECTION ALONG THE ILLINOIS CENTRAL R. R. FROM MANCHAC, LA., TO NORTH OF JACKSON, MISS.

Lafayette sands and gravels from the "basal Port Hudson gravels and sands" is to our way of thinking unnecessary and illogical. There was a period after the last coarse material in this region had been laid down, when the whole of the area represented on the maps as Port Hudson or younger, constituted one broad expanse of marsh land and extensive shallow lakes, in which clayey materials were deposited to depths of 50-150 feet. But more of these later on.

QUATERNARY SERIES

PORT HUDSON STAGE

Origin of prairie region in southern Louisiana.—The drilling of a vast number of shallow wells in the southern part of the State has been the means of solving the origin of this whole portion of the country. The auger brings up rotten wood, land shells, fresh-water shells and brackish-water shells. The shells are identical with those met with in the clayey beds now forming in the various lakes towards the southern margin of the State. In comparatively recent times, all the Port Hudson area referred to above, has been, first here than there occupied by shallow lakes containing a brackish water fauna. The rôle that *Rangia cuneata* has played in the formation of this part of the country is noteworthy. Around Jennings, for example, no one would suspect that in sinking a well less than 100 feet in depth, beds of the brackish-water species *Rongia cuneata*, are apt to be met with in layers from 1 to 5 or more feet thick. Precisely what these old conditions of affairs were like may be seen at a glance by visiting the borders of any of the large lakes in southern Louisiana, Pontchartran for example. The partial shutting off of the Gulf waters from these extensive flats was doubtless accomplished by wave action and possibly by a slight coastal rising: principally, however, by the action of the waves throwing up sand reefs, especially during great storms. Plate VIII shows one of the many remnants of more extensive lakes in this part of the State, in which the animal life and conditions of deposition we have described above can be studied to advantage. Plate IX shows one of the many long, parallel, storm-wave-formed ridges of

LAKE CHARLES VIEWED FROM WEST LAKE

GRAND CHENIER WHERE THE MERMENTAU BREAKS THROUGH THE RIDGE

LŒSS AT VICKSBURG, MISS.

southern Louisiana. The sea marsh to the right extends out to the present Gulf coast where more modern ridges are forming. To the left the Mermentau river is seen skirting the northern border of the ridge (Grand Chenier) for some distance, preparatory to breaking through and winding its way to the Gulf.

In passing from the Gulf coast inland, one encounters, first a beach with often a trace of a ridge, then a stretch of swamp or marsh with lakes and meandering bayous, then a second and third and even a fourth or fifth ridge separated by swamps or lakes according to the season and tide. But still farther north the marshes become low lands and gradually assume the very low, level stretches that rise, though almost insensibly, northward and constitute the broad treeless stretches so characteristic of the prairie region of southern Louisiana.

In this portion of the State we see no sharp line of demarcation between the Port Hudson beds and the recent alluvium and coast deposits. That the earlier part of Port Hudson time was characterized by a low or sunken condition of the lower portion of the Embayment area is not to be questioned. The thickness of the beds along the Mississippi and other large rivers and also in the well sections, prove a long continuance of sunken or sinking surface conditions. The lack of certainty in the delimitation of the lower plane of this so-called formation has already been referred to.

Loess.—We are inclined to consider the loam of the Bayou Macon hills, the lœss-like material on the southeastern flank of the Grand Gulf hill of Sicily Island, the bluff lands about Marksville, Opelousas and from there continuously southward to New Iberia as similar in origin and age to the bluff land on the east of the Mississippi from the Mississippi State line southward to Baton Rouge. All seem to be the southern representative of the typical lœss so well shown about Grand Gulf and Vicksburg farther up the Mississippi. (See Plate VII).

Alluvium and Recent Shore Deposits

A gradual rise of the land surface in the Embayment region caused the Port Hudson and lœss beds along the river channels

to soon stand out in bold relief; for with increased elevation went increased erosion. The swamp lands of west St. Landry and Calcasieu, Acadia and Lafayette parishes were drained. But lakes and swamps are in evidence along the Gulf border till this day. The very recent deposits in these low lands as well as the material of the so-called "river bottoms" constitute practically the last geological formation of the State.

Mud lumps.—So much has been written regarding the mud lumps at the mouth of the Mississippi, that any further account may seem almost superfluous. Yet after a visit to the region between South and Southeast pass, we are convinced that the origin of these peculiar objects as usually stated is erroneous.

Descriptions and figures of the mud lumps have heretofore given the impression that the material constituting the "lumps" is ejected volcano-wise out of a crater-like orifice that continually boils and bubbles with escaping gas. Along with the water and gas comes blue mud. This mud flows down outside of the vent, lava-like, and finally builds up a mud cone from 5 to 15 feet high.

We saw many places where water and gas were flowing out; the gas especially came off in considerable quantities, but in no case was the water carrying with it any noticeable amount of material wherewith to build a "lump". There is a gas spring bubbling up in the flat, surfwashed clays in the foreground of our photograph, (Plate X), but no water is running away from the crater, at least, none to speak of, less than a pint an hour.

The "lump" shown constitutes Cubit's Island. It may be reached by going down North-east pass to Bayou Balize, thence out Redfish bayou into Redfish bay. This is the most southeasterly of the large lumps. It is just south of Caney spit. Height about 12–15 feet according to stage of water. The constituent material is blue clay, evidently deposited as thin horizontal layers. It has been raised up into an anticline with dips north and south. Upon long exposure the material becomes brownish and strikingly like the banks of the neighboring passes.

To the southwest and northwest are several small lumps scarcely over 3 feet in height. Others are still just a little beneath the water level as the breakers clearly show.

On a second island farther westward another spring was seen

CUBITT'S ISLAND, A "MUD-LUMP" BETWEEN SOUTH AND SOUTH-EAST PASS

bubbling gas continually. A streak of iron oxide marked the trace of all overflow water. The temperature of the latter was 72° Fh. while the water alongside was 63° Fh. the strike of the beds on this island was in general N. W.–S. E. though a considerable variation in matters of dip were observed.

"John Landus" island is quite extensive, several hundred yards wide and perhaps a mile long. Its beds show a N.–S. strike. The temperature of a fine gas-water spring was 66½°Fh., the air at the same time was 58¼° Fh. and the Gulf close by 55° Fh.

We had no time for visiting the lumps on S-W pass but heard of some excellent ones in that direction. In case the weather is not seriously bad, the geologist will find it to his financial advantage to go by boat to Port Eads and from there row or sail east to Redfish bay, and west to Southwest pass. The lighthouse keeper at the last mentioned locality can give shelter and information; while at the former locality, east of Port Eads, there are no traces of shelter, no chance to obtain food or water.

We are still in doubt as to the exact cause of the upheavals of these mud masses near the mouth of the Mississippi, but that they rise up in domes or anticlines and preserve their regular bedding is proven by their present structure. So far as we observed none were formed as volcano-like mud cones.

Gas presumably has something to do with these upheavals; then, too, it appears to us that the difference in specific gravity in different portions of such a great mass of ooze as is here continually building out into the Gulf, may be responsible for some of the sinking, moving, re-adjusting and upheaving in certain localities.

SPECIAL REPORT
No. II

THE SALINES OF NORTH LOUISIANA

BY

A. C. VEATCH

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THE SALINES OF NORTH LOUISIANA

INTRODUCTION

The following report is intended to contain a complete account of what is known of the salt springs and wells that were formerly worked in northern Louisiana. The accompanying sketch map (Fig. 8) shows the location and relative position of the different groups of springs and wells and also the areas of which detailed sketch maps were made.

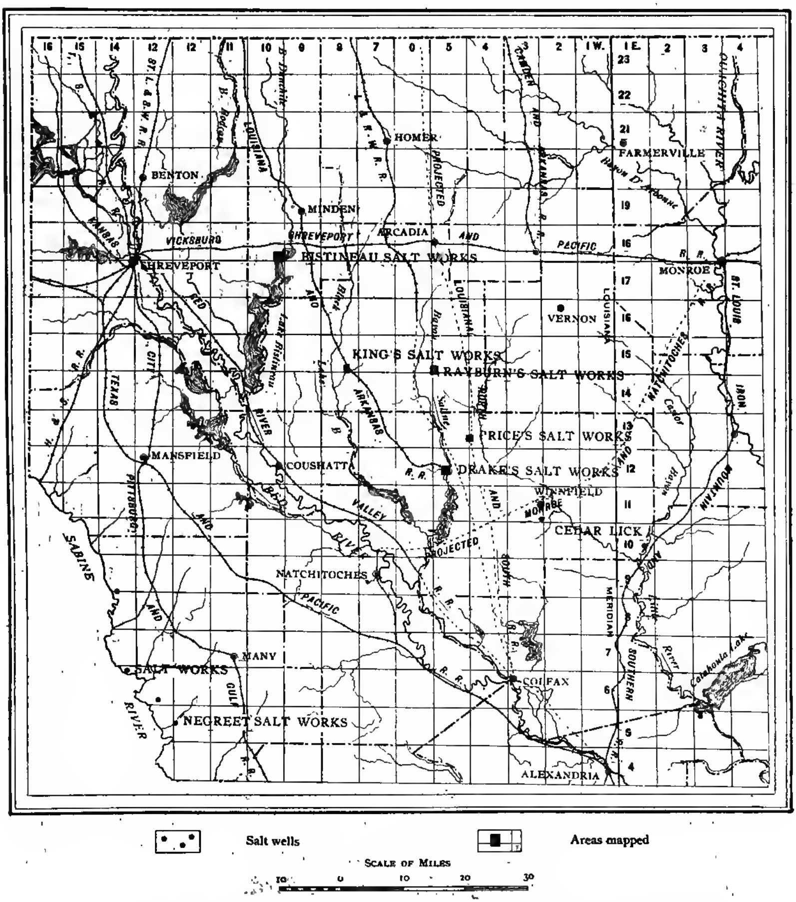

FIG. 8.—SKETCH MAP SHOWING SALINES OF NORTH LOUISIANA.

FIELD WORK

In March, 1899, the writer in making a reconnaissance of northern Louisiana passed through King's and Rayburn's Salt Works in Bienville parish. At Rayburn's an area of about a square mile was mapped and a beautifully preserved Upper Cretaceous fauna found. At King's, *Ostrea pulaskensis*, a Midway Eocene species, was found in the old dump heaps.

In the latter part of December, 1899, and in January, 1900, Bistineau, Drake's, Price's and King's Salt Works were mapped and tests made of the brines.

Method of mapping.—The sketch maps of the different salines were prepared almost wholly by pacing. All section, quarter and half section lines were followed and in most cases new lines run at the eight mile points. In regions of great detail, as in the salt well groups, lines were run east and west and north and south every thirty-second of a mile and the wells located from known points on these lines. The whole was checked by known land corners and by meandering the main roads. An open sight, 3½-inch compass was used. Relative levels were obtained with a Locke hand level.

Method of testing the brines.—The samples of brine were obtained from near the bottom of the old wells by means of a small pitcher pump, such as is commonly used on driven wells in the river bottoms, with a number of short joints of pipe so that the total length of the pipe could be regulated at will. An examination of the licks made this method seem preferable to sinking a number of new wells. Many of the old wells are still open—the timber, generally sap-pine, with which they were walled, having been preserved by the salt—and it was believed that if samples of brine could be obtained from near the bottom of the open wells they would represent the normal strength of the brines, and that a number of such samples from wells over a wide area would give a truer idea of the quality of the brines than a sample from a new well sunk at random.

Samples thus obtained were tested with a Brix Saccharometer (the only form of hydrometer which could be readily obtained), graduated to one-fifth of a degree. A number of the samples obtained were analyzed by Mr. Maurice Bird.

RESUMÉ OF PREVIOUS GEOLOGICAL WORK *

Forshey.—As early as 1850 Forshey, lecturing on the Geology of Louisiana, made the following general statement regarding the north Louisiana salt springs: "A saline bed seems to underlie the tertiary bed generally." †

Robertson.—During 1864 and 1865 J. B. Robertson was engaged in geological examinations of northern Louisiana under the direction of Gov. Henry Allen. In his official report ‡ he advances the theory that these salines are merely the "beds of ancient lakes." He records that at King's Salt Works there are 200 feet of *fossiliferous Cretaceous limestone.*‖ Whether Robertson really recognized a Cretaceous fauna or whether he merely made a happy guess we cannot tell at this time. It should, however, be mentioned that it was at this very locality, and in the dump heap of the deep well referred to, that the author found fossiliferous Cretaceous limestone last year.

Hilgard.—In 1869 Hilgard made his now classical reconnaissance of northern Louisiana. From fossils found in the Big lick at King's Salt Works and lithological characters he concluded that the material shown at the various salines and at the Winnfield Marble Quarry was Cretaceous. From the relative geographical position of the different outcrops he came to the conclusion that there was in Louisiana a Cretaceous ridge or backbone extending N.N.W. and S.S.E.§ He thought that at the

* Thanks are due to Mr. Wm. Beer, librarian of Howard Memorial Library, New Orleans, for many courtesies extended while working in the excellent collection which has been brought together through his efforts.

† Louisiana: Geology and Hydrography (Abstract of Lecture) by Caleb G. Forshey, DeBow's Review, vol. 8, p. 495, 1850; also DeBow's Industrial Resources of the Southern and Western States, New Orleans, 1853, vol. 1, p. 436.

‡ Memorial and Explorations of the Hon. J. B. Robertson in relation to the Agriculture, Mineral and Manufacturing Resources of the State; with the Report of the Joint Committee, Doc. 2d Ses. 2d Leg. La., Rept. No. 23, 1867. Also separate, New Orleans, 1867, 30 p.

‖ Ibid., p. 12. Also The Vast Resources of Louisiana by J. B. Robertson, De Bow's Review, vol. 2 (Revived Series) pp. 276, 1866; and Doc. 2d Ses., 2d Leg. La., Rept. Bureau of Immigration, p. 24, 1867.

§ Geol. Recon. of La., Am. Jour. Sci. 2d series, vol. 48, 1869, p. 343; Suppl. and Final Rept. of a Geol. Recon. of La., N. O., 1873, p. 43 and elsewhere.

beginning of the Tertiary this axis of elevation was marked by a number of disconnected islands in the Tertiary sea and that they were finally covered with deposits of the younger formations.* The brine was derived from the upper part of the Cretaceous.

Hopkins.—Hopkins' ideas of the relation of the Cretaceous and the overlying beds is given in his figure, republished in the report of the survey for 1899, page 33. It is regretted that this figure throws no light on his idea of the origin of the Cretaceous "islands"; whether they are butte-like masses formed by erosion or are local anticlines.

Lerch.—This author held that about the close of the Cretaceous time extraordinary disturbances took place which resulted in the formation of limestone peaks and mountain chains of considerable extent. One of these lines of disturbance was along the line of the supposed backbone of Louisiana and the various Cretaceous outcrops represent the partially buried peaks of this chain. He differed from Hilgard in supposing that the saline deposits were laid down in early Eocene rather than late Cretaceous time.† Lerch added to the proof of the Cretaceous age of these outcrops by finding *Exogyra costata* at Rayburn's,‡ where Hilgard had reported no fossils.

Vaughan.—Vaughan differed very markedly from Lerch. He concluded that no folding or faulting was represented in the north Louisiana Cretaceous outcrops; that they were butte-like masses, formed by erosion in the land interval which separated the deposits of the Cretaceous and Eocene and had since been covered by the younger deposits.§

Harris and Veatch.—The work of this survey in the season of 1898–99 seemed to show very clearly that the "Cretaceous backbone of Louisiana" was a myth; that in the case of the Winnfield and Coochie Brake outcrops, folding had occurred at

*Geol. History of the Gulf of Mexico, Am. Jour. Sci., 3d ser., vol. 2, 1871, p. 393.

† A Preliminary Report upon the Hills of Louisiana South of the V. S. & P. R.R., Bull. La. Expt. Station, Geol. and Agr. part 2, 1893, pp. 72-73.

‡ Bull. La. Expt. Sta., Geol. and Agr. Part I, 1892, p. 13.

§ Brief Contribution to the Geology and Paleontology of Northwestern Louisiana by T. Wyland Vaughan, Bull. U. S. Geol. Sur. No. 142, 1896, pp. 13, 14.

DRAKE'S SALT WORKS, LOWER LICK, SHOWING OLD SALT WELL, SALT KETTLES AND OPEN LICK THROUGH THE TREES

right angles to the supposed backbone or in a northeast and southwest direction; that at two localities at least, a part of the movement had occurred since the deposition of the Lower Claiborne Eocene; and that, in the case of the Five Islands, orogenic movements had taken place in the early Pleistocene.†

The operations this season have further proved the above conclusions.

PART I. DETAILED DESCRIPTION OF THE SEVERAL SALT WORKS

DRAKE'S SALT WORKS

LOCATION AND TOPOGRAPHY

Location.—Drake's Salt Works is located on Saline bayou about the middle of township 12 north, range 5 west.* In point of size the old works here are second only to Bistineau.

Streams.—Saline bayou here occupies a flat bottomed valley from 150 feet to half a mile broad, bordered by gently undulating sandy hills, covered with long-leaf pine. The bottom is heavily wooded with gum and oak, with occasional cypress swamps, except where the brines approach the surface and give rise to barren "licks" fringed with a short, stunted growth of white thorn, hawthorn and other dwarf trees.

Each of the side streams which enter the main valley has a little flat bottomed valley of its own, a miniature of the larger one. Molladoe branch on the west side and Cole branch on the east are the principal tributary streams in the region of the map.

Licks east of Saline bayou.—East of Saline bayou there are three principal "licks:" Upper lick, Jack's lick and Lower lick. Upper lick, which from the number of old wells seems

† See Rept. Geol. Surv. La. for 1899, pp. 52–62, 259.

* See map, Plate XVIII. Mr. Ed. Weeks has very kindly pointed out the locations of the following corners: the N. W., the S. W. and the S. E. corners of the N. W. ¼ of the S. E. ¼ of Sec. 21. Known corners are shown by circles at intersection of land lines.

to have been the main site of salt operations, is situated near the old mill dam. It is a somewhat circular area inclosed by low pine hills on all sides except that occupied by Saline bayou. An old channel or slough passes around the lick, which, though dry in low water, is filled in moderate stages of the bayou and on the eastern side of the lick expands into a shallow lake, where there are many old wells. When the bayou is high the whole lick is under water and to prevent the influx of flood waters, a number of the wells were surrounded with levees of earth. Near the old mill dam is the artesian well (Plate XII).

The little branch, which empties into the southwestern part of the lake, flows from a small open lick known as Jack's lick.

Between the Upper and the Lower licks is a sandy ridge 35 to 40 feet high. The Lower lick extends for about a quarter of a mile northeast and southwest, along the base of the steep hills, which bound on the southeastern side the great flat, somewhat circular area in which all the licks are situated.

A good mill site.—At the point where the escarpment south of Lower lick reaches the bayou, the creek valley is very narrow. Limestone is exposed in Rock bluff and in all probability underlies the Lower lick hills. A dam built here would have rock at either end if indeed the limestone under the bayou does not approach near enough the surface to furnish a good foundation for the whole length. A dam 15 to 20 feet high could easily be constructed and the amount of water commonly in the bayou seems to warrant the construction of a fair sized mill. Saline bayou has never yet run dry and it will be seen from the map, Plate XVIII, that the construction of a dam 15 feet high at this point would produce a very good sized mill pond which could be drawn on in case of need.

Licks west of Saline bayou.—Directly west of Rock bluff is Smith's lick. It is situated in a steep-sided little valley. North of this and south of the great bend in Molladoe branch is Big lick. This is an open sand plain with a few scattered wells. Across the ridge which separates Big lick from the main bottom is Little lick.

HISTORY OF OPERATIONS

Indian. — It was here (at the Little lick), according to the old settlers, that the Indians made most of their salt, and this statement is fully proved by the large accumulations of pot-shreds. The pottery seems to have been made on the spot, for scattered through the piles of broken pots are specimens of *Ostrea falciformis*, a fossil oyster which does not occur *in situ* at this place but is found in great abundance on the hills three or four miles to the west, and examination of the fragments shows that these shells were ground or partly pulverized and mixed with clay in making this pottery. This conclusion is strengthened by the statement of Du Pratz given below, page 54. Pottery is also found in the Upper lick on each side of the slough at the ford on the road leading to the Lower lick.

The earliest reference to salt in this region which we have seen is in the Journal of M. de Bienville.* On Mar. 22, 1700, he writes: "Four and a half leagues to the west from the Tensas we found some Ouachitas, with several pirogues partly loaded with salt." On Mar. 29, 1700, he left the village of the Ouachitas for that of the Natchitoches and after crossing Red river he records meeting "six Natchitoches who were going to the Coroas to sell salt." In his later writings there are several other references to the salt trading expeditions of the Natchitoches.

A little later Daniel Coxe† reports a location on the River Natchitock, a hundred miles from the mouth, where the Indians

*Quoted in Sieur de Bienville by Grace King, New York, 1892, pp. 100–102. The account in the Journal of M. de la Harpe, written in 1723 is substantially the same (Journal Historique de L' Établissement des Français a la Louisiane, Nouvelle-Orléans et Paris, 1831, p. 32; also: Translation, from Am. Phil. Society MSS. in Historical Collections of La. by B. F. French, vol. iii, 1851, p. 18).

† A description of the English province of Carolina, by the Spainards called Florida and by the French La Louisiane, and also of the great and famous River Meschacebe, or Missisipi, and the five vast navigable lakes of fresh water and the parts adjacent. Together with an account of the commodities of the growth and productions of the said province. And a preface containing some considerations of the consequences of the French making settlements there. By Daniel Coxe. Second edition, London, 1726, pp. 10–11. (Quoted in full, Geol. Surv. La. Rept. for 1895, pp. 11–12.)

make salt for themselves and for trade with the neighboring nations. This account seems to have been founded on the reports of Indian guides, for Coxe does not appear to have traveled in Louisiana, although an expedition sent out by him seems to have entered the mouth of the Mississippi and proceeded as far as the English Turn.

The account of M. La Page DuPratz,* who was for some years a resident of the country is more complete. He describes the operation of making pottery as follows : "I shall add, that pretty near the *Natchitoches* we find banks of muscle-shells, such as those of which Cockle Island† is formed. The neighboring nation affirms that according to their old tradition, the sea formerly came up to this place. The women of the nation go and gather these shells, and make a powder of them, which they mix with the earth, of which they make their pottery or earthenware. However, I would not advise the use of these shells indifferently for this purpose, because they are naturally apt to crack in fire : I have therefore reason to think that those found at the Natchitoches have acquired their good quality only by the discharge of their salts, from continuing for so many ages out of the sea."‡

The following description, by the same author, seems to refer to the springs at the site of Drake's salt works : "On the north side (of the Riviere Rouge or Riviere des Natchitoches) and pretty near the Natchitoches, there is, as is said, a spring of water very salt, running only four leagues. This spring, as it

* Historie de la Louisiane, Contenant la Découverte de ce vaste Pays ; sa Description géographique ; un Voyage dans les Terres ; l' Historie Naturelle ; les Mœurs, Coûtumes and Religion des Naturels, avec leurs Origines ; deux Voyages dans le Nord du nouveau Mexique, dont un jus qu' à la Mer du Sud ; ornée de deux Cartes et de 40 Planches en Taille douce, 3 vols., Paris, 1758.

Also : The History of Louisiana or of the Western Parts of Virginia and Carolina ; containing a description of the Countries that lie on both sides of the River Missisipi ; with an Account of the Settlements, Inhabitants, Soil, Climate and Productions by M. LaPage DuPratz (Trans. from the French), London, 2 vols., 1763.

† In Mississippi Sound.

‡ Ibid. Paris ed. vol. 1, pp. 163-164, London Trans., vol 1, p. 219.

comes out of the earth, forms a little river, which during the heats, leaves some salt on the banks.''*

Early white operations.—The exact date when the white man first made use of these springs is uncertain. It would be expected from the nearness of the post of Natchitoches that these springs would have been used soon after the establishment of the post, but Du Pratz says nothing of its use although he speaks of the "French trucking coppers" to the springs near Catahoula lake.†

One of the first accounts of the work of white man at this point was given by John Sibley in a letter to Gen. Dearborn dated Natchitoches, Apr. 10, 1805.‡ Not having personally visited the works he makes a slight mistake as to the geographical location of the salt springs. He says: "About twelve miles north of Natchitoches, on the northeast side of the river, there is a large lake called *Lac Noiz*‖; the bayou of it communicates to the Rigula de Bondieu, opposite Natchitock, which is boatable the greater part of the year. Near the lake are the salt works, from which all the salt that is used in the district is made; and which is made with so much ease, that two old men, both of them cripples, with ten or twelve old pots and kettles, have for several years past made an abundant supply of salt for the whole district; they inform me they made six bushels per day. I have not been at the place, but have a bottle of the

* Ibid. Paris ed., vol. 1, p. 298, Lond. trans., vol. 1, pp. 276–277.

† Ibid. Paris ed., vol. 1, pp. 307–308; London trans., vol. 1, p. 283. See below, page 91.

‡ Louisiana: An Account of the Red River and Country Adjacent by John Sibley, American Register, vol. 4, pp. 49–67. Am. State Papers (vol. 4) Indian Affairs, vol. 1, pp. 725–773, Wash., 1832.

These two accounts are almost identical, differing only in the spelling of two or three words and in the substitution of periods in the first for semicolons in the second. The account quoted is from Am. Register. An extract taken verbatim from Sibley is given in Judge François-Xavier Martin's History of La., N. O. 1827, vol. 1, p. lxi, and in the reprint N. O. 1882, p. 19. Samuel Brown in The Western Gazetter or Emigrant's Directory, Auburn, N. Y., 1817, p. 121 has made use of the same source of information.

‖ Spelled Lac Moir in Am. State Papers, Lac Noiz in Brown and Lac Noir in Martin's. The latter is evidently correct. Black lake and Saline lake have clearly been confused.

water brought to me which I found nearly saturated. The salt is good. I have never had better bacon than I make with it. I am informed there are twelve saline springs now open, and by digging for them, for aught any one knows, twelve hundred might be opened. A few months ago Captain Burnet, of the Mississippi territory, coming to this place by the Washita,* came by the salt works, and purchased the right of one of the old men he found there, and has lately sent up a boat, with some large kettles and some negroes, under the direction of his son; and expects when they get all in order, to be able to make thirty or forty bushels a day. Captain Burnet is of the opinion that he shall be able to supply the Mississippi territory, and the settlements on the Mississippi, from Point Coupée, upwards, lower than they can get it from New Orleans and bring it up."

Maj. Amos Stoddard in his Sketches of Louisiana, published in 1812, states that only three wells had been sunk, from which "seven laborers produce two hundred and forty barrels of salt per month at an expense of one hundred and forty dollars." He supposed that a hundred wells of equal value might be sunk.†

Darby in 1816 states that the salt works are situated on the land of Mr. Postlewaite on Saline bayou about 25 miles by road from Natchitoches; nearly "upon the 32° N. lat. and on the 92° 52′ W. long." ‡

"Here", he adds, "the water is drawn from wells perforated in a sandy bottom similar to the beeches of a river." ‖ Salt from this locality was at this time transported as far as Natchez and New Orleans. The price received for the salt sold to the inhabitants of the Natchitoches and Rapides settlements was from one to two dollars per barrel. § He marks "Postlewait's Salt Works"

* Given *Washington* in Am. State Papers. It would seem more probable that Washita was correct.

† Sketches, Historical and Descriptive, of Louisiana. By Maj. Amos Stoddard, Phila., 1812, p. 400.

‡ A Geog. Desc. of the State of La., etc., by William Darby, Phila., 1816, pp. 29 and 211.

‖ Ibid., p. 36.

§ The Emigrant's Guide to the Western and Southwestern States and Territories, etc., by William Darby, Phila., 1818, p. 89.

ARTESIAN WELL, DRAKE'S SALT WORKS

on his map * and it is therefore so marked on a number of maps of the United States, published about this time, which copied Darby's Louisiana.

George Graham, Commissioner of the General Land Office, in 1824 reported two salt springs north of Red River as follows: One in 12 N., 5 W.; the other in 13 N., 4 W. He gives the following claimants to salt springs on Saline bayou in the *county of Natchitochez*: John Burnet, Benj. Goodwin, Alexander Baillie, heirs of James Morrison, Samuel Coburn, Pierre Rosseau. †

The local demand so increased that in the early forties Mr. Reuben Drake, who was then in possession of the lick and whose name has since remained attached to it, attempted to obtain a stronger brine by deep boring. Eight wells were bored. One, situated near the mill-dam was pushed to a depth of 1011 feet. ‡ The others appear to have been only from one hundred to two hundred feet deep. In each artesian brine was found. In the deep well near the mill dam the pressure was sufficient to lift the water into a tank 35 feet above the opening of the pipe.

The flow at this time was from eighteen to twenty gallons per minute. § As the brine was much weaker than that obtained from the shallow wells it was not used to any extent. At present the large 10-inch pipe projects only about a foot and a half above the ground (Plate XII) and the rate of flow has decreased owing to a partially successful attempt to plug the well.

About the time the wells were drilled a dam was thrown across the main bayou and a saw mill and a grist mill erected. Drake's furnace, which is now represented by a mound about 200 feet long, was near the eastern end of the dam. The water power developed at the grist mill was used to run the pump which drew water from the well in Little lick, on the west side of the bayou. Drake's ditch, the trench in which the wooden pipe was laid, can

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* A Map of the State of Louisiana with part of the Mississippi Territory from Actual Survey by Wm. Darby, Phila., 1816.

† Report of the Commissioner of the General Land Office in relation to Lead Mines and Salt Springs, 18th Cong. 1st Sess. House Ex. Doc., vol. 6, No. 128, p. 14, 1824.

‡ Hilgard, Final Rept. Geol. Recon. of La. N. O. 1873, p. 31; The Salines of Louisiana, Mineral Resources of the U. S. for 1882, p. 556.

§ Ibid., p. 556.

be readily traced through the woods from the bayou, near the proposed site of the railroad bridge, to the very edge of the Little lick. Drake dug shallow wells in nearly all of the licks and the wells from which the strongest brine can now be obtained are nearly all old Drake wells.

The property passed into the possession of Mr. J. C. Weeks who commenced to make salt about 1854. He used two wells, one in Little lick (Plate XI) and the other in Upper lick. During the salt season he made from 30 to 40 bushels a day.* In 1859 the saw mill was destroyed by fire.

War operations.—Before the war nearly all the salt used in the middle Southern States was imported. At the outbreak of the war this source of supply was partially cut off and as the efficiency of the federal blockade increased salt commenced to become scarce. People came for salt from distant points in the state and as the war went on people from Mississippi, Alabama and Arkansas joined the crowds. With the advance of the federal troops from New Orleans to Alexandria many of the sugar plantations were abandoned and the great sugar kettles together with the negroes belonging to the plantations were taken to north Louisiana to make salt. Drake's received its share of these refugees. Those who occupied the land east of the bayou paid Mr. Weeks a nominal rent, varying with different individuals and different locations; those who occupied sites in Sec. 20 did so as squatters, for that section was then reserved by the general government for its salt springs.

Slaughter and Weeks had a very large establishment on the hill between Little and Big licks. They had six evaporating pans, three about 30 feet long and 8 feet across composed of a number of square pans bolted together, and three halves of steamboat boilers. These were mounted on rude foundations of ferruginous sandstone. Brine for these furnaces was obtained from Drake's old triple well in Little lick, just south of the road. It was lifted 25 feet to the furnaces by a horse power pump. Brine was also obtained from a couple of small wells just west of the furnace on Molladoe branch.

* Statement of his son, Mr. Ed. Weeks. I am indebted to Mr. Weeks for much information on the operations here during the war.

The same firm also made salt in the Lower lick. They used brine from one of Drake's old wells, marked with a star on Plate XVIII and shown in Plate XI. This well furnished the strongest brine that the writer was able to find at Drake's, and Mr. E. T. Weeks states that it has always been considered the strongest well. The output of this firm is reported to have averaged about 100 bushels per day.

In December, 1863, Mr. Cobb Manlove of Vicksburg, on behalf of the Confederate government, contracted with Mr. J. C. Weeks for all the salt he could produce at the rate of $10.00 per bushel, at the works; a contract which Mr. Weeks had reason to regret for soon his neighbors were selling all the salt they could make at from $12.00 to $15.00 per bushel.

From the number of wells and old kettles on the southern part of the Upper lick it would seem that this was one of the principal foci of the war operations. Smith was the principal salt-maker at the lick which still bears his name.

At the close of the war work soon stopped. Salt could not be produced here, by the primitive methods employed, at a cost that would allow it to compete with the salt made on a large scale by improved methods elsewhere. Soon only a few of the families in the neighborhood resorted here yearly and finally even these ceased to come.

GEOLOGY

Surrounding country.—This salt lick is surrounded by deposits belonging to the Lower Claiborne Eocene. Three or four miles to the west are numerous little black land prairies covered with *Ostrea falciformis* and *O. johnsoni*, var. It was from this locality that the Indians probably obtained the shells found in the accumulation of pot-shreds on Little Lick. Five miles to the southeast, Lower Claiborne fossils are found near the 24th mile board on the Sparta–Montgomery road in ferruginous concretions. Near Saunder's Church, about six miles southeast, there is a little prairie with *Anomia*, *Plicatula filamentosa*, *Pseudoliva vetusta* and *Ostrea falciformis*. Eight miles to the northwest, beyond Dugdemona bayou, on the road to Gansville there is an outcrop of Lower Claiborne.

Cretaceous.—The most important, and almost the only exposure, on the area under consideration is at Rock bluff. Here there is an outcrop of grey, granular, sandy limestone containing very imperfect plant impressions, occasional veins of calcite and nodules of pyrites. Lithologically it is identical with the Coochie Brake limestone. The exposure is about 50 feet long and shows 15 feet of stone. The dip is about 45°, S. 18° W. The peculiar escarpment on the south side of the lick and the extreme narrowness of the creek valley at this point seem to owe their origin to this bed of limestone.

In the licks only a few of the shallow wells have struck rock. In nearly all, the brine was obtained in sand. The exceptions include several wells near the southeastern corner of Upper lick. Here the old dump heaps show specimens of dark, almost black, slightly crystalline limestone filled with veins of calcite. Large fragments of limestone are found in the dump heaps of the wells in the little lick on the upper part of Cole branch. These are in some ways similar to the concretions found in the basal Eocene and they may prove to be of that age.

The artesian well is said to have passed through solid limestone for its whole depth, 1011 feet, and Hilgard reports that a few of the fragments taken from the hole which were to be seen at the time of his visit were almost identical with the "rotten limestone" of Alabama and Mississippi, or upper Cretaceous. The brine from this well has a temperature of 75° F. and the gas which escapes with it will support a flame half an inch in diameter and six inches high.

Old Tertiary.—On Molladoe branch, just above the two northernmost wells, is a small outcrop of grey, laminated sandy clay dipping about 10° N. W. This has the general appearance of the lower Eocene beds but in the absence of fossils its exact age is uncertain. In the material thrown out from the wells, at this point, are fragments of grey leaf limestone of the same general appearance as that occurring in the Lignitic Eocene farther west.

Gravel.—Many of the old dump heaps show quantities of white and variously colored chert and quartz pebbles. These are particularly common at Big lick and along the Molladoe.

Conclusions.—Though the data here presented is in itself not conclusive, yet when taken in connection with the facts gained from nearby known Cretaceous outcrops there can be little doubt as to the nature of the phenomena shown here. A line connecting the principal well groups would form an irregular oval with its major axis northeast and southwest. This peculiar distribution of the wells taken in connection with the two observable dips [one at Rock bluff and the other on the Molladoe (see map Plate XVIII)], the abundance of limestone near the surface in the easternmost lick, the topographic features of the hills bound ing the Lower lick, all seem to indicate that there is here a dissected dome. This is graphically shown in Fig. 9, which repre-

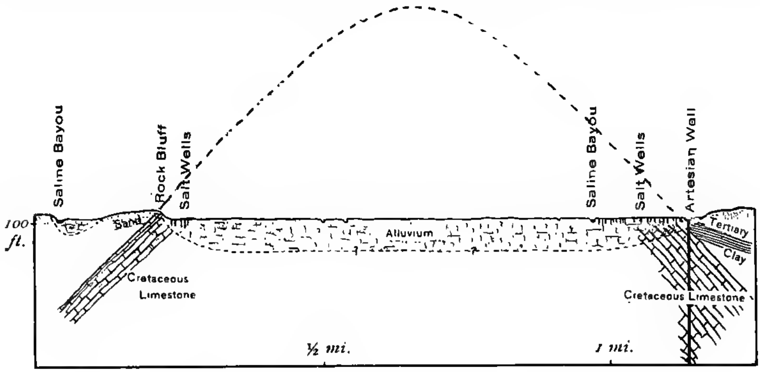

FIG. 9.—PARTIALLY IDEAL SECTION OF DRAKE'S SALT.

sents a partially ideal section along the line A-B, Plate W. The figure shows the location of the wells in the alluvium near the outcrop of the upper portions of the Cretaceous limestone—only a few of the wells seem to approach the rock. Lerch has published a section of this locality in which the Cretaceous limestone is represented as horizontal, with the Eocene and other material resting unconformably upon it.*

Hydrometer tests of brine.—Brines from many of the wells were tested on the spot with a Brix Saccharometer, graduated to one-fifth of a degree. These results, when compared with the analyses, will give something of the relative strength of the brine on different parts of the lick.

*See Sec. 2, p. 71, Bull. La. Expt. Station, Geol. and Agr., Part II, 1893.

HYDROMETER TESTS: DRAKE'S SALT WORKS

(Readings in degrees Brix)

No.	Depth of Well.	Depth from which sample was taken.	Surface reading. (Brix.)	Surface temperature. (Far.)	Sample reading. (Brix.)	Tem. sample. (Far.)	Specific gravity.	Remarks.
1	11 ft.	9.5 ft.	—	—	7.5	57°	1.029	
2	11	8	—	—	7.6	56°	1.029	
3	10	9	—	—	8.1	63°	1.0322	
4	8	7	—	—	7.65	56.5°	1.0298	
5	7	5.5	—	—	7.7	56°	1.030	Brine yellow.
6	14	10	6.2	—	6.5	61°	1.025	Clear white brine.
7	7	6.5	8.6	—	10.7	56°	1.042	Clear white brine. Analysis No. III, page 63.
8	6	5	1.1	—	10.4	60°	1.041	Water a little green. Analysis No. IV, page 63.
9	5	4	2.5	—	5.8	62°	1.0229	Water yellow.
10	1000+	—	—	—	3.5	75°	1.0149	Clear white brine. Large amount of gas.
11	10	9	1.7	50°	6.9	61°	1.027	Slightly yellow.
12	7	6	2.2	58°	9.4	60°	1.0376	Very slightly colored. Analysis No. I, page 63.
13	15	9	6.3	56°	6.9	55°	1.0267	
14	6	5	0.7	50°	1.6	56°	1.0058	Slightly yellow.
15	11	8	7.1	52°	7.1	53°	1.0273	White brine. Analysis No. II, page 63.
16	10	8	6.9	56°	7.2	56°	1.0277	
17	6	5	6.2	57°	6.5	57°	1.0245	
18	5	4	6.6	56°	7.1	56°	1.0253	
19	8	6.5	2.5	53°	7.4	62°	1.0277	

1. Well S. E. side of Upper lick in opening of hollow leading to Jack's lick.
2. Ditto.
3. Well on extreme northern point of Jack's Island, Upper lick.
4. Well between 2 and 3, Upper lick.
5. East side of Upper lick.
6. Jack lick.
7. Lower lick south side, old Drake well. This is the same as No III in the table of brine analyses.
8. Upper lick, southwest side, well just west of for l, surrounded by embankment same as No. IV in the table of brine analyses.
9. Upper lick, southwest side. Leveed well in middle of bayou at ford.
10. Artesian well.
11. Little lick, well just east of Goldonna road.
12. Little lick, old Drake well south of Natchitoches road. Same as No. I in table of brine analyses.
13. Well on Molladoe branch just west of Slaughter and Week's furnace.
14. Big lick, southern part.
15. Smith lick. Same as No. II in the table of brine analyses.
16. Smith lick.
17. Smith lick.
18. Smith lick.
19. Smith lick.

Analyses of brine.—Hilgard collected brine from the artesian well and has published the following analysis :

Analysis of Brine from Artesian Well

(Hilgard)

Chloride of Sodium	93.30
Chloride of Magnesium	1.78
Carbonate and sulphate of calcium	4.92
	100.00

Total amount of solids in brine about two per cent.

Samples collected by this survey have been analyzed by Mr. Maurice Bird with the following results :

ANALYSES OF BRINES FROM DRAKE'S SALT WORKS

(Maurice Bird)

	I	II	III	IV
Sodium chloride	4.90	3.55	5.58	5.44
Calcium chloride	.184	.127	.303	.356
Magnesium chloride	.142	.133	.135	.159
Alumina	.061	.066	.072	.055
Other solid matter	.083	.044	.070	.030

I. Little lick, west side, old Drake well.*
II. Smith's lick.
III. Lower lick, old Drake well.
IV. Upper lick, south side, in slough.

* The wells whose waters were analyzed are shown by stars on the map, Plate XVIII.

PRICE'S SALT WORKS*

LOCATION AND TOPOGRAPHY

Location—Price's Salt Works is six miles northeast of Drake's, in Sec. 25 and 30, 13 N., 4 and 5 W., near the edge of Dugdemona bottoms. In point of importance, as shown by the number of old wells and ruined furnaces, it ranks fourth in the north Louisiana salines.

Topography.—The wells and open lick spaces are arranged in a circle about the base of a hill, known as Lick Hill, which rises 96 feet above them. Lick Hill is completely separated from the surrounding hill land masses. South and west the hills are high and the country broken, on the north lower and cut by the fairly broad valley of Cypress bayou. On the east, a ridge, broken in three places by stream channels, separates the lick from Dudgemona bottoms or swamp (see Plate XIX). This ridge is highest in its central portions where it reaches an altitude of 55 feet. The general shape of the Lick Hill is well shown on Plate XIX but several of the minor topographical features are but imperfectly represented, notably the several sink-hole like depressions which are scattered over the hill. The most pronounced one is shown on the map just south of the apex of the hill. It is about 75 feet in diameter and 15 feet deep. Other sink holes, in the field, have been almost obliterated by plowing.

Licks.—The licks are scattered around the base of Lick Hill and are separated from each other by growths of lowland trees.

* Acknowledgments are due to Mr. T. Peterson for the location of the land corners shown on the map of Price's. Hilgard (Salines of Louisiana, Min. Res. for 1882, p. 556) has given this locality as Sec. 22, township 12 north, range 17 west, which is very clearly in error.

They are level, entirely devoid of vegetation but bordered by stunted trees. The soil is a light grey, silty clay with some pyrites and calcareous concretions. Nearly all the wells are situated in or near the borders of the licks although some are now in the surrounding woods. The locations and shape of the licks are so well shown on the map that a detailed description of each seems unnecessary.

Streams.—Double branch, which enters Lick valley at Smith's lick, flows northward and joins a little branch from the west. The united streams under the name of Black bayou, after turning eastward, flow through Big lick into Cypress bayou. Formerly Black bayou flowed along Boggy slough but during the war the lick was much cut up with wagons and shortly afterwards, taking advantage of an old road, the stream cut across to Cypress bayou. During periods of extreme high water in Dugdemona bayou, Big lick is covered to a depth of from two to three feet.

The southern part of the lick is drained by Powder Spring branch. Springs are common along the ridge separating the lick from the bottoms.

HISTORY OF OPERATIONS

Early operations.—No accumulations of pottery, similar to those found at Drake's were found here and if the Indians came to make salt it was only at rare intervals and in a desultory manner.

The first printed recognition of the locality that we have seen is on Tanner's Map of Louisiana * where it is marked "Salt Lick."

In 1824 George Graham, in his report on the salt springs of northern Louisiana gives its location as "Township No. 13, Range No. 4 West."†.

The exact date of the first attempts at salt making here is not known. Mr. John Walker moved to this part of the country in 1859 and found old wells on the lick.

* Map of Louisiana by H. S. Tanner, Phila., 1820.

† Report of the Commissioner of the General Land Office in Relation to Lead Mines and Salt Springs by George Graham, 18th Cong., 1st Sess. House Ex. Doc., vol. 6, No. 128, pp. 14–15, 1824.

War operations.—This lick shared with the others a period of intense activity during the war. The first to make salt at this time were George Christian and Conrad Stark. Their wells were situated in the upper part of what was afterwards known as Smith Lick.

Mr. George Price of Ruston, La., has kindly furnished the following account of his father's operations here: "In September 1861, Col. George Richard Price, J. W. McHenry and John Sholars began the work of salt making at what is now known as Price's Salt Works. They dug a number of wells before they found water of sufficient strength and quality to begin operations. They bought old sugar kettles from the sugar farms above Alexandria, La., with a capacity of from 500 to 3000 gallons each. They first put up a large furnace on the order of the old sugar furnaces in lower Louisiana, consisting of 10 kettles with the largest kettle at the mouth of the furnace and ranging smaller back to the chimney. The water was pumped up by home-made pumps with tubing of long pine poles bored out by hand. These pumps were erected in wells dug in a circle and connected by levers attached to a zigzag wheel, which was attached to a main shaft in the center like the shaft wheel of an old fashioned horse-gin. This was turned by horse power. The water was conveyed to a large tank or vat at the furnace by troughs dug out of split pine saplings of about six inches in diameter. This cold water was turned into the first seven large kettles and boiled to a strong brine, then dipped up by hand and poured into a settling vat and from there emptied into the three upper or smaller kettles for graining and boiled down to salt. When the market was dull this salt was scooped up and put into draining vats to dry, and when well drained and dry was stored in a salt house but when the demand was great it was frequently sold from the draining vat at from $3.00 to $10.00 per bushel of 60 pounds. The price varied with the demand and I have seen fifty wagons waiting their turn. After this my father became the owner and operator of this part of the works and formed a partnership with a Mr. J. H. Mays in another furnace also located near, and a little east of the old furnace. This furnace consisted of smaller kettles and of an old boiler

split by hand into halves and was operated as the other except that the water was pumped by hand. The first furnace made from 40 to 100 bushels per day, depending on the amount of water available, the second about 40 bushels. The water tested about one bushel of salt to eight of water and would hardly float an egg. My father also established a furnace in Rayburn's Salt Lick in 1863. There the water was much stronger, one to six instead of one to eight. The water was plentiful and inexhaustible."

On the first point of hills northeast of Price's are the ruins of McHenry's furnace and south are Yawger's. Others who made salt in considerable quantities and who continued work for the greater part of the war were: Thos. Smith and W. T. Kidd at Smith's lick, Durbin and Tilly on the east side, and Payburn between Smith and Price. Besides these there were great numbers who came and stayed but a short time and for one reason or another moved on. Tilly and Smith are reported to have produced about 35 bushels of salt daily. Three or four hundred bushels would then seem to be a very liberal estimate of the daily output of Price's in its best days.

No rent was paid for the privilege of making salt as the land was at that time government property.

The last attempt to make salt on any considerable scale was made by a man by the name of Bynum. In 1869 he purchased from Mr. Ed. Weeks 15 of the old kettles which had been used at Drake's and for a short time he made salt at the site of the old Smith furnace. About the same time Barnum and McCarty made salt at the old Tilly furnace.

No deep wells have been attempted here, all are open wells from 8 to 15 feet.

GEOLOGY

Limestone outcrop.—The hard, light grey, granular, sandy, leaf-bearing limestone which is exposed at Drake's is also exposed here, though the single exposure is by no means so satisfactory. This small outcrop is on the south side of the high knoll in the ridge which separates the lick from Dugdemona bottoms, at the point where Boggy slough (old Black bayou) makes a little bluff.

All the pieces seem to be out of place and some were clearly disconnected masses, so the direction of dip could not be determined accurately. It seemed, however, to be 4 or 5 degrees, a little south of east. About 150 yards, a little south of west of this outcrop, the dump heaps of two of the old Tilly wells show fragments of limestone of exactly the same character. In the dump heap of one of the wells in the eastern part of Deer lick fragments of dark blue limestone were found. The sink holes on Lick Hill indicate a bed of soluble material beneath, probably limestone.

Well sections.—Two shallow holes were made in the lick with a "well punch," an instrument very much like a small post-hole digger. In one, on Smith's lick, quicksand was reached at a depth of 3 feet and became so troublesome at 7 feet that the hole was abandoned. A second hole was sunk on Tilly lick near the well in which limestone was found. It showed the following section:

Well Section Tilly Lick

A.	Light sandy clay	2 feet
B.	Yellow clay mottled with red	5 "
C.	Very dark blue clay	3 "

Hilgard reports the find of vivianite in some of the old dump heaps.*

Vertebrate remains.—"Big bones" are reported from a well just west of Payburn's furnace at a depth of 8–10 feet. Hopkins states that mastodon bones have been found here.†

Conclusions.—This lick seems, like the other important salines of northern Louisiana, to be a Cretaceous outcrop, but the evidence at hand is hardly conclusive. A line connecting Price's and Drake's is parallel to the Coochie brake—Winnfield anticlinal, and seems to represent a second line of weakness. It may be that these two points represent points of maximum elevation along a fold extending between these salines, but any positive evidence that such is the case is at present lacking. An outcrop

* Supplementary and Final Rept. of Geol. Recon. of La., N. O., 1873, p. 31, Mineral Resources of the United States for 1882, La. Salines, p. 556.

† 2d Rept. Geol. Sur. La., 1871, p. 6.

of limestone is reported, though a search failed to confirm the report, in the pine woods south of Yankee Spring church, midway between Price's and Drake's.

Hydrometer tests.—Hilgard reports* the brine here stronger than at either King's or Rayburn's; a conclusion that we were unable to verify. The following are the results of the tests of the different wells:

The wells on Tilly and Durbin's licks are nearly all filled and no tests could be made of the brine. Brine pumped from a depth of four feet in the hole sunk on Smith's lick tested 3.7° Brix, at a temperature of 50° F. The brine obtained from the hole sunk near the Tilly furnace was very muddy. It tested 10.7°, but this extremely high test is believed to have been due to the large amount of suspended silt in the water. It tasted weaker than the water from the big well, Smith's lick which tested only 5.7°.

Analysis of brine.—Mr. Maurice Bird has made the following analysis of the brine from well number 3 in the following table:

Analysis of Brine, Price's Salt Works

(Maurice Bird)

	Per cent.
Sodium chloride	3.14
Calcium chloride	.079
Magnesium chloride	.138
Alumina	.050
Other solid matter	.030

* Supl. and Final Rept. N. O., 1873, p. 31.

HYDROMETER TESTS: PRICE'S SALT WORKS

(Readings in degree Brix)

No.	Depth of well.	Depth from which sample was taken.	Surface reading. (Brix.)	Tem. surface. (Far.)	Sample reading. (Brix.)	Tem. sample. (Far.)	Specific gravity.	Remarks.
1	13 ft.	10 ft.	1.0°	58°	5.7°	63°	1.0225	Clear white brine.
2	9 "	7 "	2.3°	52°	3 5°	60°	1.0137	Clear white brine.
3	11	10 "	4.6	51°	6.1°	65°	1.0241	Analyzed 3 31 per cent. solid matter; of which 3.14 was common salt.
4	9 '	7 "	——	——	4.6	57°	1.0177	Brown brine. Tastes of iron. Well surrounded with fragments of blue limestone.
5	5 '	3½ "	1.7	——	4.2	57°	1.0161	Water slightly colored with vegetable matter.
6	8 "	7 "	——	——	5.1	54°	1.0193	Clear white brine.
7	14 "	8 "	0.0	44°	6.2	56°	1.0245	Clear white brine.

1. Smith's lick: Big well southeast side of lick.
2. Smith's lick: Well west of big well.
3. Smith's lick: Well north of big well.
4. Deer lick: Western well.
5. Big lick.
6. Price's lick.
7. Price's lick.

OLD SALT KETTLES, RAYBURN'S SALT WORKS

RAYBURN'S SALT WORKS

LOCATION AND TOPOGRAPHY

Location.—Hilgard* and Lerch† have both given the location of this saline as Sec. 34, 15 N., 5 W. The writer has carefully examined the deeds in the possession of Mr. A. G. Whitlow, the present owner of the place, in which the land is described as Sec. 31, 15 N., 5 W. It is in Bienville parish about eight miles from Bienville, the present terminus of the Louisiana and Northwest railroad.

General features.—The main lick is a flat, circular, slightly swampy area of 40 or 50 acres (see Plate XX). It is surrounded by gently sloping hills which, on two sides, at a distance of half a mile reach an altitude of sixty feet. As in the other licks, the open space in which the wells are situated is fringed with a few stunted hawthorn, thorn and other dwarf trees which increase in number and pass into the surrounding forest of oak, hickory, gum and short-leaved pine.

Around the edge of the valley are numerous circular mounds about sixty feet in diameter and from three to four feet high. They are of the same general type as those seen in southern Louisiana and on the upland flats of Caddo and Bossier parishes.

The southern end of the lick is quite swampy and during heavy rains is flooded to a depth of two or three feet. The valley is drained by Foust's creek.

Many of the old kettles and boilers are still in place. Plate XIV shows a portion of the row of boilers on the western side of the lick. Something of the barren appearance of the lick can be

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* Supl. and Final Rept. p. 29. In the report on the Salines of Louisiana, Hilgard has given the locality as Sec. 34, township 15 north, range 17 west. Price's is given as 17 west, King's as 20 west and Bistineau as 22 west. Hilgard has evidently used a map of Louisiana in which the Arkansas range numbers were given at the top of the map and has taken these as the true range numbers of the Louisiana townships. This has resulted in an error of plus 12 in the numbers, as the meridian used in the land division of Arkansas was the 5th Principal Meridian and in Louisiana [west of the Mississippi river] the Louisiana Meridian.

† Bull. La. Expt. Station ; Geol. and Agr., Part II, p. 72, 1893.

gained from the foreground of this picture. Some half dozen old halves of steamboat boilers show on the old furnaces in the midst of a clump of bushes and trees which have sprung up since the war. In the background may be seen the trees on the farther side of the lick.

On other parts of the lick large sugar kettles brought from southern Louisiana and peculiar rough sugar-loaf shaped kettles, cast at Alexandria in 1863, are common. Plate XIII shows a group near the central part of the lick.

HISTORY OF OPERATIONS

Early operations.—No trace of Indian operations have thus far been found on this lick. On account of its inland position it was not until the early forties that salt was made here regularly. About that time Mr. Foust, the owner of the land, commenced on a modest scale.

War operations.—This work was continued until the civil war, when the restrictions imposed on the importation of salt by the federal blockade caused salt to have a very greatly enhanced value. The fame of Rayburn's lick spread, and in 1862 men came from far and wide, bringing with them gangs of negroes, to make salt. Shelters were hastily built, the valley was dotted with wells from 15 to 20 feet deep, which were protected from the water of occasional freshets by low levees. The natural mounds were utilized for furnace sites and near the central part of the valley, where these mounds were not found, artificial ones were made. Large iron kettles from four to seven feet in diameter were mounted on rude foundations made of ferruginous sandstone. Large boilers were obtained, split in half and wooden bulkheads inserted in the ends. These were mounted on similar foundations of sandstone. (See Plate XIV.) In the latter part of 1863, a large number of small, thick, sugar-loaf shaped kettles were cast at Alexandria for use at this place. One of these which has been patched, is shown bottom side up in the foreground of Plate XIII.

A rent of 2½ bits (37½ cents) per bushel was charged for the privilege of making the salt and for the wood consumed. The receipts of the owner of the land at this rate are said to have

ROW OF OLD BOILERS USED FOR EVAPORATING SALT, RAYBURN'S SALT WORKS

amounted to $375.00 per day. This would give a daily production of about one thousand bushels. Mr. Sampson Rayburn, who married the widow Whitlow, a daughter of Mr. Foust, was placed in charge and collected the rent. It was in this way that the lick became known as Rayburn's.

At the close of the war the works were almost entirely abandoned. Occasionally a small amount of salt was made for the neighborhood and Mr. G. C. Whitlow made salt here as late as 1877.

GEOLOGY

Hilgard's Well Section.—Hilgard has published the following section of a well in the southeastern part of this lick:

Well Section Rayburn's Salt Works

(Hilgard)*

A.	Whitish mud of the lick, with ferruginous spots and at its base frequently bearing balls of calcite....	6 feet
B.	Silicious gravel often cemented into a conglomerate by crystallized calcite........................	6–7 "
C.	Greyish or white crystalline limestone, horizontally banded, fragile, often covered with 5–6 inches crystallized aggregates of calcite, on a dark banded base of the same.................	6 "
D.	Dense, banded gypsum, pure	2 "

The old dump heaps about the wells show large quantities of variously colored quartz and chert gravels. Fragments of dark grey and yellow fissured crystalline limestone and of white or bluish-white gypseous limestone are quite abundant in some of the old dumps.

Cretaceous outcrops.—On the little knoll east of the lick (see map, Plate XX) the soil is very black and waxy, with numbers of *Gryphæa vesicularis*, a few *Exogyra costata*, and pieces of selenite scattered over the surface. In the little gulleys is exposed a very fine grained, white, chalk-like limestone containing a well preserved Upper Cretaceous fauna. Limestone containing poorly

* Supl. and Final Rept. of Geol. Recon. 1873, p. 30.

preserved fossils is to be seen about half a mile north of the old works (Plate XX). Near this one or two wells have been dug but their brine does not appear to have been used to any considerable extent.

Cretaceous fossils.—The following is a list of the species collected at this locality (mainly Stanton's identifications):

Exogyra costata
Gryphæa vesicularis
Ostrea plumosa
Ostrea larva
Pecten burlingtonensis
Spondylus, sp.
Neithea quinquecostata
Crassatella vadosa
Inoceramus barabina ?
Legumen planulatum
Linearia metastriata
Avellana bullata
Hamulus onyx
Dentalium cf. *ripleyanum*
Baculites anceps
Heteroceras
Ptychoceras

Most of these have been figured and described by Prof. Harris in the report of this survey for 1899, pp. 292–297, Plates 49, 50 and 51.

Other outcrops.—The hills surrounding the lick are composed entirely of grey sand containing a few iron concretions and a plowed field between the two Cretaceous outcrops shows this sand very well. To the southwest the sand gradually becomes more and more clayey until it is replaced by a stiff yellow clay mottled with red. In the iron concretions found in this clay were casts of *Venericardia* and a few imperfectly preserved *Gastropoda.*

Vertebrate remains.—Hopkins reports mastodon bones from this locality.*

Conclusions.—From the paleontological evidence furnished by the fossils the white chalk-like limestone belongs to the uppermost division of the Upper Cretaceous. It is lithologically quite different from beds of the same horizon in the surrounding states. Nothing concerning the exact relation of the gypseous limestone, found in the wells, to the fossiliferous limestone found in the hillsides could be learned beyond the fact that the former is clearly stratigraphically below the latter. Although no dips

* Second An. Rept. Geol. Surv. La., 1871, p. 6.

could be determined, there can be little doubt that if they could be observed they would represent either a dome or anticline.

Hydrometer tests.—Hydrometer tests reveal the fact that the brine here is stronger than at Price's. The best brine tested is however not so strong as that found at Drake's.

HYDROMETER TESTS: RAYBURN'S SALT WORKS

(Readings in degrees Brix)

No.	Depth of well.	Depth from which sample was taken.	Surface reading. (Brix.)	Tem. surface (Far)	Sample reading. (Brix.)	Tem. sample (Far.)	Specific gravity	Remarks.
1	18+	10	0.1°	62°	6.7°	63°	1.0265	Water a little dark, probably due to decaying vegetable matter.
2	16	10	5.1°	62°	10.0°	64°	1.0401	Do.
3	8	7	2.4°	63°	8.5°	64°	1.0339	Do.

All these wells are near the center of the lick and represents the strongest brine that the writer was able to find.

Analysis of brine.—Water from well No. 3 shows the following analysis:

Analysis of Brine: Rayburn's Salt Works

(Maurice Bird)

Sodium chloride	4.60
Sodium sulphate	.022
Calcium sulphate	.322
Magnesium sulphate	.029
Alumina	.061
Other solid matter, partly in suspension	.030

KING'S SALT WORKS*

LOCATION AND TOPOGRAPHY

Location.—This old salt works is 14 miles due west of Rayburn's, in the low lands bordering Bayou Castor, a tributary of Black Lake bayou. It is half a mile from the line of the newly constructed Louisiana and Arkansas Railroad, and ranks fifth in size in the salines of Louisiana.

Valley of Bayou Castor.—The valley of Bayou Castor is of a type common in north Louisiana, a broad, flat-bottomed valley, seemingly out of proportion to the size of the stream occupying it, with steep hills on the south and sloping hills on the north. These valleys seem to owe their present shape more to a change in the position of the base level, which has caused the streams to deposit silt in their valleys, than to base-leveling action.

At this point the bottom land is about 160 feet† above the sea. It is low, somewhat swampy and is moderately heavily timbered. Scattered about over it are little irregular mounds, 2 to 3 feet high and 50 feet or more in diameter, which are very similar to the mounds which occur in places over Louisiana, Texas and Arkansas.

The licks.—Here and there are open spaces or spaces sparcely timbered. These are generally covered with swamp palmetto but in places are entirely bare. These are the "lick spots."
Open lick, the only lick south of Bayou Castor, is entirely covered with palmetto. No wells were sunk here. The main site

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*The writer is indebted to Mr. H. P. Wardlaw, the owner of the lick for the location of the northwest corner of Sec. 35 and for the southeast corner of the S. W. ¼ of the N. W. ¼ of Sec. 35.

† The level of the deepest part of Castor Bayou at the point where it is crossed by the Louisiana and Arkansas Railroad, according to information furnished by Col. G. Knoble, the chief engineer of the road, is 152 feet. On the railroad maps the 160 foot contour passes along the edge of the level land bordering the creek. There is but a slight correction for these levels: The elevation of the top of the U. S. E. bench mark at Sibley is 191.8 feet. The elevation at the same point in the railroad elevations is 191.00 feet.

KING'S WELL, KING'S SALT WORKS, LOCALITY FROM WHICH CRETACEOUS WAS FIRST REPORTED IN LOUISIANA

of salt operations, Big lick, is just north of the bayou. It is almost entirely covered with water after a heavy rain. Scattered around on the little elevations at the edge of the lick are the ruined furnaces. Upper lick, northeast of Big lick, is almost entirely covered wilh scrub palmetto. Several old wells are still to be seen here. (See Plate XXI.)

About 500 yards northwest of the main lick and near the Sparta-Coushatta road is a little lick which contains King's well. (Plate XV.) About 200 yards west of King's well is a salt spring, which furnishes a very weak brine.

HISTORY OF OPERATIONS

Indian.—A few pot shreds and arrow-heads are found on the ridge between Bayou Castor and Open lick and seem to indicate a temporary Indian camp site. From the dearth of pot-shreds and also from the distance to the best brine we judge that the Indians came here occasionally more to hunt the animals which frequented the lick than to make salt.

Early white operations.—Salt operations were begun here by Mr. King about the same time that work was commenced at Rayburn's. He dug a shallow well and striking rock drilled in it to a depth of 136 feet, according to Hilgard.* The water rose to within two feet of the surface. Here he built his salt house and every year, after the crops were harvested, the negroes were brought to the salt house and the year's supply of salt made. Neighbors brought their negroes and availed themselves of the opportunity.

War operations.—This salt works shared with the others a period of great activity during the war. Numerous wells, from 10 to 20 feet deep †, were sunk in Big lick and large kettles and halves of boilers were mounted on rude foundations of sandstone near the wells. I have been unable to get any information regarding the daily production of the works during the period of greatest activity.

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* Supl. and Final Report of Geol. Recon. of La., 1873, p. 29.

† Statement of Mr. H. P. Wardlaw, grandson of Mr. King.

GEOLOGY

Cretaceous.—This locality is of decided historical interest as it was here that the Cretaceous was first definitely recognized in Louisiana. We have already referred (p. 49) to Robertson's report of fossiliferous Cretaceous limestone from King's in 1867. Hilgard was, however, the first to bring forward proof that the Cretaceous occurred here. He found in several of the old dump heaps at Big lick a "soft gray calcareous mass containing very perfect specimens of *Graphyœa pitcheri* and *Exogyra costata.*" It has already been shown*, from specimens collected by the writer from one of the old dump heaps in Big Lick in 1899, that *G. pitcheri* is in reality *O. pulaskensis*, a typical Midway Eocene oyster but the finding of a number of Cretaceous fossils the past year around King's well makes it seem probable that Hilgard was correct in his identification of *E. costata* and that a few wells in Big Lick pass through the Midway into the Cretaceous. He states that specimens of *Janira* were reported to have been found in digging a well near King's old well. Here crystalline limestone is reported at a depth of 5 feet and continued 20 feet to the bottom of the well.

When the water was removed from the part of the King well now open (the salt water was prevented from filling it by the height of the old pipe tube) a number of fragments of grey fossiliferous limestone were obtained from the sides of the well.

The following species have been identified:

Exogyra costata	*Gryphœa vesicularis* var.
Lima pelagica	*Turritella trilira*
Anomia	*Liopistha protexta ?*

Cretaceous from Neal's well.—Half a mile northeast of King's well at the point where the Sparta-Coushatta road crosses the railroad, a well dug by T. W. Neal showed the following section:

Well Section Neal's Store.

A.	Yellow sandy clay mottled with white. Contains a few white quartz pebbles....................	17 feet
B.	Very dark grey, sandy, laminated clay with *Ostrea larva*, *Ostrea* sp., ...	4 "

* La. Geol. Survey, 1899, pp. 63-64.

The water obtained from this well is quite brackish.

The material from Neal's well is the first representative, which has been found in Louisiana, of the beds of dark colored sands and clays which characterize the upper beds of the Upper Cretaceous in Arkansas and Texas. All the other fossiliferous Cretaceous deposits in Louisiana, though pronouncedly the uppermost Cretaceous from the character of the fossils, are lithologically more like the lower beds of the Upper Cretaceous.

Midway Eocene.—Thus far fossils of this stage have been found only in one old dump heap near the center of Big lick. An outcrop of limestone is reported in the bed of one of the old bends of Bayou Castor, a little west of north of the center of the southwest quarter of Sec. 35. This place was covered with water at the time of the writer's visit and hence could not be examined. Hilgard reports an outcrop of soft, fossiliferous, aluminous limestone, similar to the "rotten limestone" of Mississippi, in the bed of Bayou Castor and probably refers to this outcrop.

Surrounding Country.—The hills to the south are covered with masses of ferruginous conglomerate. To the northward are high sand hills (Vaughan's Sparta Sands.)

Vertebrate remains.—Mr. H. P. Wardlaw, grandson of Mr. King, states that the horns of some large animal, together with a number of large bones, were dug from one of the wells in the southwestern part of Big lick. He describes it as being hollow, a true horn (*cornua cava*) rather than a tusk.

Robertson evidently referred to this find when he said: "I saw taken from one of these lacustrine basins the horn of an extinct animal, which horn measured thirteen inches in diameter and, though fractured, was yet over three feet in length and still retained the horny laminations and odor."*

Asphaltum.—Robertson reports asphaltum from this locality† but thus far his report remains unverified.

Tests and analysis of brine.—All the old wells in Big lick were so filled with sediment that it was impossible to obtain samples of the brine. Two shallow holes were sunk with a "well-

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*Memorial and Explorations of the Hon. J. B. Robertson, N. O., 1867, p. 11.

† Ibid., pp. 15–16. Also DeBow's Review, vol 2, p. 277, 1866.

punch" in the large group of wells; the first, 4 feet deep, passed through white sand mottled with yellow. This hole filled during the night with quicksand, and the water obtained tested 1.2° Brix at 56°F. The second was 7½ feet deep and passed through one foot of white sand containing small iron concretions and 6½ feet of dark colored clay. Brine tested 6.5° at 55°F., but neither of these can be regarded as a fair test.

In the old King well the water was pumped out of the open part of the well and the old wooden pump tubing found intact. The water rose to within a foot and a half of the top of the tube, and by inserting a section of iron pipe attached to a small pitcher pump brine was readily obtained from the old well. The first water pumped was very black from decayed vegetable matter, and tested as high as 14.7° Brix, but in a short time it became quite clear and tested 13.4° (S. G. 1.0544). Water was pumped from the well for more than an hour and at the end of that time it still tested 13.4,° which probably represents the true strength of the brine.

A sample of brine from this well has furnished the following analysis :

Analysis of Brine, King's Salt Works

(Maurice Bird.)

	Per cent.
Sodium chloride	6.940
Calcium sulphate	.010
Calcium chloride	.152
Magnesium chloride	.135
Alumina	.148
Other solids	.065

The slight amount of gypsum contained in the water is probably responsible for the "crusts of limy matter" which are reported to have been formed on the sides and bottom of the kettles and which made it necessary to "chip them out" occasionally.

TADPOLE LAKE, BISTINEAU SALT WORKS

1. HIGH WELL
2. CRETACEOUS OUTCROP
3. GOVERNMENT WELL

BISTINEAU

LOCATION AND TOPOGRAPHY

Location.—An examination of Fig. 8 and Plate XXII will show Bistineau Salt Works occupying a portion of the old bottom of the Lake Bistineau in the southwestern corner of T. 18 N., R. 10 W. The old wells are in portions of sections 25, 26, 35 and 36.* It is the largest of the old salt works in northern Louisiana.

Topography.—It seems quite impossible to reconcile the present topography of the region and the shape of the shore line of Lake Bistineau as given on the maps of the General Land Office and we are forced to the conclusion that only a few points on the lake were actually located, enough probably to give a crude idea of the general shape and extent of the lake, and that the details were supplied by the fertile brain of the surveyor in his office.

On these maps the northern end of the lake is represented as about a mile above the works (see Fig. 8, which is based on the Land Office maps). The head of the lake is now a number of miles below the works. Lake Bistineau is one of a series of lakes formed along Red river valley by the elevation of the bed and banks of the river by deposits of silt during the raft period and the consequent choking of the outlets of the tributary stream valleys.‡ At the time of the government land survey, in the early thirties, the lake had reached and probably passed its maximum size. After the removal of the raft the river was confined to the main channel by the closure of the outlet bayous and it commenced to erode the sediment deposited during the raft period. As this erosion progressed the tributary streams commenced to remove the silt deposited in their outlets and so

* This location is based on lines run from the northeast and northwest corners of the S. E. ¼ of the S. W. ¼ of Sec. 26; corners established by Mr. Jack Stewart, a surveyor and a land owner, to whom I am indebted for many courtesies, and for the major part of the information given under the history of the war operations.

‡ The origin of lakes of this type is discussed at length in a report on the Shreveport Area, pp. 158, 163, 167–69, 172, Geol. Survey of La., Rept. for 1899.

lower the level of the lakes. In this way Sodo lake has been almost destroyed and the areas of all the lakes along Red river, owing their origin to these causes, have been very materially lessened. Lake Bistineau has shared in this general lowering of levels and may be expected to decrease. In the region about the wells the lake is now only represented by Bayou Dauchite.

The islands or hills.—Skirting the edge of the pine hills and at a distance of several hundred yards from them and in the old lake bottom are a number of elevated island-like areas which rise ten to fifteen feet above the surrounding bottoms. At the time when the lake covered the whole lick these were islands and during the war a number of them received names: Stansberry island, Coon island, Frenchman island, and Salt island (see Plate XXII).

The licks.—The saline nature of the soil seems to have prevented the growth of trees before the existence of Lake Bistineau for there are none of the old tree stumps here, remnants of the pre-lake forest, which are found in other parts of the old lake. During the lake period the waters probably leached the salt from the upper layers of earth, for since the removal of the water by the partial drainage of the lake, trees have been able to grow. As late as the war the whole of the old lake bottom, in the region of the map, was bare—a great white plain of sandy silt—and one could look from one group of wells to another. Now it is bare only in the vicinity of the old well groups where wells have shown that brine exists nearest the surface. Elsewhere there is a growth of gnarled dwarf trees: thorn, hawthorn, "elbow bush" and "button bush" with here and there a few cypress. In places the growth is so dense that it is difficult to force one's way through on foot and quite impossible on horseback.

The wells are arranged very nearly in a circle about three-quarters of a mile in diameter (see Plate XXII); commencing in the old bed of Crane lake on the east side of Salt island they follow Tadpole slough around to the head of Stansberry island; the eastern side of the circle is completed by the large group of wells known as Potter's pond, New Orleans and the group east of Bayou Dauchite near the ford.

Probably the largest collection of wells is at Potter's pond.

(See map and Plate XVII.) Other notable groups are at Tadpole lake, the head of Salt island, Crane lake, New Orleans (between Potter's pond and the bayou) and, on the eastern side of the bayou.

HISTORY OF OPERATIONS

Indian.—This locality being well removed from Red river did not come under the direct observation of the early French explorers and there are not the references to it that there are to places nearer the early routes of travel.*

Evidences of Indian occupation are found on the south and east of Potter's pond, which owes its name to the accumulations of pot shreds about it. This pottery lacks the shells found in that made at Drake's. On the northern end of Salt island there are quantities of flint chips and partly perfected arrowheads. The material for the arrowheads was derived from the gravel beds which cover the hills bordering the bottoms and which underlie the lick at a depth of 3 or 4 feet.

Early white operations.—In 1846, B. M. Thompson and W. C. Howard carried samples of brine from Potter's pond to their homes and boiled it to test its strength.† The quantity made evidently did not satisfy them for it was not until some years later that salt was made here in any considerable quantities; about 1850 the Hodges brothers made a little.

The people of this region received their supplies from the Red river settlements by boats which came up Lake Bistineau and Bayou Dauchite. At this time the old town of Minden marked the head of navigation. The year of 1855 is remembered by all the old people as a year of extreme drouth; the lake was so low that no boats could come up from Red river and the salt supply ran so low that the whole neighborhood resorted to the well known lick to make salt. Common iron wash kettles, of which every family had one or more, were used in boiling the

*DuPratz in speaking of the brine springs at Drake's says that in the country whence this spring takes its rise there are several springs of salt water. (Hist. de la Louisiane, etc., par M. Le Page DuPratz, Paris, 1758, vol. I, p. 278.)

† Interview with Mr. Thompson.

brine. W. G. Gillcoatt seems to have been one of the largest salt makers that year. With the resumption of navigation salt making at this place almost, if not entirely, ceased.

War operations.—The supply of salt was again cut off a few years later by the federal blockade, but this affected a much wider area than that affected by the low water in Lake Bistineau. People came from Texas, Arkansas and Mississippi, and in 1862, 1863 and 1864 it is estimated that there were from 1000 to 1500 people engaged in salt making at this point.

The land, being a portion of a lake bottom, was still held by the general government, so there was no rent to pay. Many slave owners and overseers who had fled with their negroes from regions occupied by union forces came here and made salt. John Colaign, an Irishman, with a large number of negroes supposed to come from Mississippi, made salt in large quantities at Potter's pond.

One of the principal salt makers at Tadpole lake was Stansberry, who made salt under contract with the Confederate government. His house and the houses of his laborers were on the island, which bears his name. His two principal wells, now known as the Government Wells, are situated north of Tadpole slough on either side of the section line (Plates XVI and XXII). They are the largest wells at the head of Tadpole slough. One surrounded by a levee and situated on slightly higher ground is known as the High well. It is circular and about 20 feet in diameter.*

One of the most interesting things to the geologist studying the historical side of these old works is the appearance of a Frenchman by the name of Thomassy at this place the latter part of 1862 or the spring of 1863. He leveled a large area on Tadpole slough, dug a large well and laid off the ground for a series of basins in which to make salt by solar evaporation. He started a house on the southern end of what is known as Frenchman island, but being a man of somewhat fastidious tastes was regarded with disfavor by the local people. It is reported that he employed a man to accompany him to cut all the roots and fill all the holes on the road leading to the works so that the buggy

* It is shown by a star on Plate XXII.

would run easily and smoothly and so that he would not be roughly shaken. The people regarded this as quite unnecessary and came to the conclusion that his whole scheme was visionary. When he had finished leveling the ground and had it laid out with stakes ready for excavation, a party of men from Arkansas arrived at the works. They looked over the ground and concluded that Thomassy had too much ground for one man and that the land he had leveled would make a very good place to sink wells. They immediately began to dig wells and when Thomassy protested told him that if he didn't "dry up and leave the country they would put him up a tree at the end of a rope." This was a time of war when might was right and the victory went to the stronger. Thomassy left, saying that he would make complaint to President Davis. It seems quite probable that this was M. Raymond Thomassy, author of Gèologie Pratique de la Louisiane, one of whose pet schemes was the making of salt by solar evaporation.*

A number of the old stakes and a portion of the leveled space are still to be seen just east of the Frenchman's well.

At Bistineau, as at the other old works, platforms were built around the wells and the brine, after being elevated to the level of the platforms with homemade wooden pumps, was conveyed to the furnaces by troughs supported on forked poles. A number of these old supports may be seen in the foreground of Plate XVI. Old sugar kettles, wash kettles and steamboat boilers were used for evaporating pans and "grainers." High water pre-

*In 1855 in a paragraph in DeBow's Review (vol. 18, p. 538) he speaks of some new improvements in the making of salt which he introduced in Italy in 1848. In 1859 he addressed a memorial to the several legislatures upon the subject of the promotion of salt manufacture in the South on a new process invented by himself. (DeBow's Review. vol. 26, p. 119). In 1861 he wrote on "The New Salt Manufacture of the Confederate States" (DeBow, vol. 31, pp. 442–446). This article contains a copy of a "Prospectus of a Joint Company for Sea Salt Manufacture, on an Improved and Patent Plan, under the Superintendence of Mr. Raymond Thomassy." It seems quite probable that Thomassy intended to employ his method at Bistineau and that the action of the Arkansas men caused Louisiana to lose the benefit of a very valuable and possible highly beneficial experiment.

vented continuous operations, the work generally commencing in June and continuing until about Christmas.

The price of salt, which was from a dollar to a dollar and a half a sack just before the war, rose to ten dollars per bushel just before the fall of Vicksburg. There seems to be no way of even approximating the amount of salt made here between 1862 and 1865.

Operations since the war.—At the close of the war, operations on a large scale ceased. A few families in the neighborhood still continued to resort to the place and to make salt during the summer months. One old negro, "Old Dan Bryan," continued work until his death in 1892. He seems to have worked up quite a little salt trade in the neighborhood. He made most of his salt from an old well in the upper part of Crane lake, which is known as Old Dan Bryan's well. (It is represented by a star on the map, Plate XXII.) After Bryan's death no one made salt here till the summer of 1897 when Austin Blackshear and Willoughby Bacon, both colored, made a few bushels.

In 1883 the commissioners appointed by Webster Parish to make collections to represent the parish at the New Orleans Cotton Exposition bored a hole on the upper end of Salt island, a little southwest of Old Bryan's well.

About 1890 George Cutting, with two assistants, under direction of New Orleans parties, drilled two wells on the hill north of Tadpole lake in search of rock salt. A third hole was started but the drill broke and it was abandoned.

GEOLOGY

Cretaceous.—On the northern edge of Stansberry island there is an outcrop of yellow marl or very soft limestone. It extends almost to the government wells and contains numbers of large *Gryphæa vesicularis* and *Exogyra costata*, both typical Upper Cretaceous species. A number of fragments of white, highly crystalline, fossiliferous limestone were found here, evidently taken from the wells. This limestone is lithologically very much like the highly crystalline limestone at Winnfield and contains the fauna found in the soft, chalk-like limestone at Rayburn's.

The following species have beeu obtained at this locality :

Gryphæa vesicularis	*Pecten quinquenarius*
Exogyra costata	*Pecten simplicus*
Lima	*Cucullæa*

These specimens were obtained in the shallow water shown on the left side of Plate XVII.

Robertson makes the following statement regarding limestone at this place : "There is near Lake Bistineau, in close proximity to the salt works, an immense bed of dolomite, or magnesium limestone." The writer was unable to verify this statement.

The wells.—Nearly all the wells dug here were quite shallow, seldom exceeding a depth of ten feet. Mr. Jack Stewart reports that along Tadpole slough and in Crane lake they commonly passed through 4 feet of dark colored vegetable muck or peat-like clay and then white sand and gravel containing brine. There is sufficient hydrostatic pressure to cause water to flow from a number of the old wells ; as at the Frenchman's well and a number of wells at the head of Salt island. Inflammable gas escapes from the Frenchman's well ; from the wells at the head of Salt island ; and from a well near the government well at the head of Tadpole slough.

It is reported that during the war a deep well was bored near the mouth of Hodges creek. This well at a depth of about 125 feet struck a rock which they could not penetrate. The precise location of this well could not be learned but from its approximate location it would indicate the westward component of the dip at this point to be not less than 9° nor more than 20°.

The well drilled in 1883 on the northern edge of Salt island, just west of Bryan's well, showed the following section :

Well Section Salt Island, Bistineau Salt Works

A.	White sand, with fresh water	10 feet
B.	Black clay not passed through	35 "

Vertebrate remains.—In the Frenchman's well several vertebræ, the leg bones and a portion of the tusk of some large animal, probably a mastodon, were found at a depth of about 15 feet. This well is hence known as the Elephant well.

The surrounding country.—The hills for about half a mile west of the old works are covered with water worn gravel. Scattered through the gravel beds are large masses of quartzite, showing little or no erosion. It seems hardly probable that they have been transported for any very great distance. Masses weighing two or three hundred pounds were seen but attempts to locate the parent ledge proved futile.

Weak brine is found much to the north of the old works. It is reported near the bridge over Honey bayou on the Minden-Doyline road (S. E. ¼ S. 15, T. 18 N., R. 10 W.). A well dug at the old saw-mill on Dr. T. J. Tabor's place, half a mile west of the Honey bayou bridge and near the V. S. and P. R. R. track, showed at a depth of 20 feet, a bed of shells, mostly gastropods. Below this was a black clay. At a depth of 36 feet a hard substance was struck which the well-diggers were unable to penetrate and the well was abandoned. This well was dug some years ago and none of the shells could be obtained. East of this, on the land of Mr. Harvill, S. W. ¼ of S. W. ¼, Sec. 13, T. 18 N., R. 10 W., a few specimens of *Gryphæa vesicularis* have been picked up in an old field. No outcrop could be found and the proximity of a number of old graves makes it seem probable that the shells had been carried there from the outcrop at the old salt works to decorate the graves.

West of the gravel belt the land rises to a low flat upland covered with little mounds. These upland flats seem to belong to the Port Hudson deposits.* Toward Fillmore there is a bit of rolling Eocene upland. The ferruginous concretions, on this area, contain a few casts of Eocene fossils, whether Lower Claiborne or Lignitic has not yet been satisfactorily proved.

About two and a half miles south of the old works in the N. E. ¼ of Sec. 7, T. 17 N., R. 9 W. Lerch obtained fossils from a well. Vaughan reports the following Lower Claiborne species from this locality: †

Pleurotoma gabbi	*Ancilla ancillops*
Pappilina dumosa var. *trapaquara*	*Phos scalatus*
Phalium globosum	*Corbula aldrichi* var. *smithvillensis*

* For a more detailed discussion of the Upland flats see Rept. Geol. Surv. La., 1899, pp. 189–195.

† Bull. U. S. Geol. Surv., No. 142, 1896, pp. 38–48.

POTTER'S POND, BISTINEAU SALT WORKS, SHOWING OLD SALT WELLS

Lower Claiborne fossils occur in considerable numbers in the vicinity of Mt. Lebanon.

Conclusions.—The arrangement of the wells here is extremely like that at Drake's. On the whole it suggests an eroded dome with the wells following the outcrop of the brine bearing horizon. The ideal section at Drake's would then in a general way represent the condition at Bistineau. The fossils obtained furnish conclusive evidence as to the age of the deposit.

Analyses of brine.—Hilgard reports that a sample of salt received by him during the war from this locality was quite fine, and of a greyish tint. On treatment with water about 5 per cent of insoluble matter, chiefly earth, remained. The salt solution contained:

*Analysis of Bistineau Salt**

(Hilgard 1862)

Chloride of sodium (by difference)	99.68
Chloride of calcium	0.17
Chloride of maguesium	0.10
Sulphate of calcium	0.05
	100.00

It is regretted that a series of hydrometer tests was not made here, but at the time of the examination of these works the necessary apparatus was not at hand. The brine at Tadpole lake and along Tadpole slough seems to have been rather weak. Samples collected at points indicated by stars on Plate XXII gave the following results:

BRINE ANALYSES: BISTINEAU SALT WORKS

(Maurice Bird)

	Bryan's Well.	Potter's Pond.	Head of Salt Island.
Sodium chloride	8.450	7.810	3.800
Calcium chloride	.234	.301	.081
Magnesium chloride	.102	.156	.083
Alumina	.056	.052	.056
Other solid matter	.088	.061	.058

*The Salines of Louisiana by E. W. Hilgard, Min. Res. of the U. S. for 1882, p. 555, Wash., 1883.

OTHER SALINES

SALT WORKS NEAR SABINE RIVER

Negreet Salt Works.—About half a mile above the mouth of Bayou Negreet, in the S. W. ¼ of Sec. 24, T. 5 N., R. 13 W., salt was made on a small scale during the war. The brine here issues from the ground in the form of springs. The best ones are in the bed of the bayou. The brine was obtained by sinking hollow cypress logs, of such a length that their top projected above the surface of the bayou, vertically over the springs. The brine was then pumped up with homemade wooden pumps and carried by troughs to the kettles on the bank. The only trace of the old works now visible is a single well on the south bank of the bayou. The brine here issues from Lower Claiborne marl.

Other works.—Near Stone Coal bluff on the Sabine river in Sec. 33, T. 6 N., R. 13 W., is a small open lick showing probably half a dozen old wells and several old furnace sites. No outcrops were seen but the surrounding country is upper Lignitic Eocene.

Another small saline, which was worked during the war, is reported in Sec. 2, T. 6 N., R. 14 W., about half a mile from the river. It is described as a treeless space covered with white sand. The operations here were not so extensive as those near Stone Coal bluff.

Hilgard reports that salt and soda were made by Governor Allen from water obtained from pits dug in the Sabine bottoms two miles below Myrick's ferry*.

Sibley speaks of a saline which the inhabitants of Bayou Pierre resorted to, situated between Bayou Pierre and the Sabine river. The exact location of this saline is not known.†

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* Supl. and Final Rept. of a Geol. Recon. of the State of La., N. O., 1873, p. 22. See also Robertson Memorial and Explorations, N. O., 1867, p 13.

† Am. Register, vol. 4, p. 58, also, Am. State Papers, Indian Affairs vol. 1, p. 728, Wash., 1832.

CATAHOULA SALT SPRINGS

Early French accounts.—Du Pratz has given a very interesting, though somewhat inaccurate account of these salt springs. He says:* "After we have gone up the Black river (Riviere Noire) almost thirty leagues†, we find on the left a brook of salt water, which comes from the west. In going up this brook about two leagues we meet with a lake of salt water, which may be two leagues in length by one in breadth. A league higher up to the north, we meet another lake of salt water, almost as long and broad as the former.

"This water, doubtless, passes through some masses of salt; it has the taste of salt without the bitterness of sea water. The *Indians* come a great way off to this place, to hunt in the winter, and make salt. Before the French trucked coppers with them, they made upon the spot pots of earth for this operation; and they returned home loaded with salt and dry provisions."

Later references.—Sibley‡ and Stoddard‖ have both mentioned an excellent brine spring on Catahoula lake. Darby speaks of salt springs on the "Ouachitta and Dugdomoni," which are equal to those on the Saline.§ This may refer to this locality.

So far as is known these springs were not utilized to any considerable extent during the war and it is inferred that the brine here is weaker than the brines farther west.

Hopkins, who examined the region in 1871, found numerous weak brine springs issuing from beds he considered of Port Hudson age. He was inclined to regard them as of very doubtful

* Histoire de la Louisiane, etc., par M. Le Page DuPratz, Paris 1758, vol. 1, pp. 307-308; Lon. trans., 1763, vol. 1, p. 283. An extract from this work entitled a Geographical Description of Louisiana Translated from M. Le Page DuPratz appeared in Gentlemen's Magazine, January 1763, pp. 265-267.

† Hunter and Dunbar give the distance from Red river to the mouth of Little river as 22 leagues [Am. State Papers (vol. 4), Indian Affairs, vol. 1, p. 732.] The maps of the Ouachita river survey (U. S. E. under direction of Maj. J. H. Willard, 1896) gives the same distance as 91 miles.

‡ Am. State Papers, Indian Affairs, vol. 1, p. 727, Wash., 1832; Am. Register vol. 4, p. 56. His spelling is "Acatahola."

‖ Sketches of Louisiana, Phila., 1812, p. 400. Speaks of "Ocatahoula lake."

§ Emigrant's Guide, New York, 1818, p. 89.

economic value. He reported a stratum of salt crystals, five-eights of an inch thick and eighteen feet from the surface, in Capt. L. D. Corley's well.*

SALINES NEAR DUGDEMONA BAYOU

Castor salt springs.—This saline is located on Castor bayou about four miles above the mouth of the Dugdemona. Old settlers on the Ouachita river state that people who attempted to make salt here abandoned it after a time and went to Drake's and Price's and Rayburn's. Dr. A. R. Kilpatrick gives the following account of them in 1852:† "Salt springs of the very best quality are here, in the western part of the parish on the west side of Castor bayou, four miles from the fork. The water boils up in the springs, and where it has spread over the ground, the whole surface is covered with crystals. Mr. Fowler settled here as early as 1804, and has made salt in a poor way up to this time. The early settlers were constantly in the habit of resorting here to make their yearly supplies of salt, when it was selling at $2.50 per bushel. Some years ago a well was dug here in a low place in the glade, and the water gushed up over the mouth, and is running that way yet."

Cedar lick.—Cedar lick is situated about two miles south of Winnfield on a branch of Cedar creek, a little to the east of the Winnfield-Colfax road. The open space is covered with a growth of scrub palmetto. Both Kilpatrick‡ and Hilgard § have mentioned this locality. Its waters seem never to have been used to any considerable extent for making salt.

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* Third An. Rept. Geol. Surv. of La., 1872, p. 178.

† The Parish of Catahoula by Dr. A. R. Kilpatrick, De Bow's Review, vol. 12, 1852, pp. 268-269.

‡ DeBow's Review, vol. 12, 1852, p. 269.

§ Supl. and Final Rept., N. O., 1873, p. 33.

PART II. GENERAL CONSIDERATIONS

ECONOMIC CONDITIONS

RELATIVE VALUE OF THE NORTH LOUISIANA BRINES

The two tables here presented enable one to compare the strength and purity of the Louisiana brines with the brines from a number of important localities in this country where salt is made on a large scale with profit. It will be seen that in point of strength and purity the Bistineau brine outranks the brine from the Ohio valley region in Ohio and the Kanawha district in West Virginia. The King's brine, while slightly behind these in the amount of sodium chloride it contains, is considerably superior to them in purity; there being about 7 per cent of impurities in the solid contents of the King's brine compared to 20–30 per cent in the Ohio and West Virginia brines. Results from the other old works are not so favorable, the analyses falling well behind those from any brine spring, in this country, which has thus far proved of commercial importance as a source of salt.

So far as our information goes Bistineau and King's are therefore the only ones of the north Louisiana salines which at present furnish brines which could be used profitably for making salt. On the important question of how much brine either of these localities could be expected to supply daily there is no exact information at present. At Bistineau only shallow wells have been sunk and the brine, which in some cases is under pressure enough to flow over the top of the well, comes in from the bottom and sides. At King's the brine from King's old well rises to within two feet of the surface and a hand pump seems to have very little effect on its level. The Bistineau saline is liable to overflow and would have to be protected by a levee or pipes so laid to the producing wells that, in times of high-water, they could be pumped from the hill-land. The position of these salines with reference to the railroads, now existing in the state, is shown on the maps accompanying this report. Bayou

TABLE I.—ANALYSES OF BRINES OF THE UNITED STATES

Localities.	Sodium chloride.	Calcium chloride.	Magnesium chloride.	Bromides.	Calcium sulphate	Magnesium sulphate	Other matter.	Total solids.	Analyst.
Saltville, Smyth Co., Va.....	25.975*				0.3221	0.1029		26.400	G. H. Cook.
Grand Saline, Texas†									
Hutchinson, Kansas†									
Manistee, Mich	25.4156	0.3449			0.4395			26.20	A. H. Prescott.
Banks, Bay Co., Mich	19.8595	2.9611	1.2612		0.0722			24 154	Dr. C. A Göessmann.
Saginaw valley (1st well) Mich.	17.9120	2.1420	1.5220		0.1160		0.2200	22.0170	Prof. Douglass.
Port Austin, Mich	17.6161	3.1274	1.5675		0.0129			22.3239	Dr. C. A. Göessmann.
East Saginaw, Mich.........	16.8710	3.2873	1.7743	0.0401	0.0982		0.0745	22.1570	Prof. Chilton.
Syracuse, New York.........	15.3570	0.0795	0.1449	T	0.5747			16.1590	Dr. C. A. Göessmann.
Geddes, New York	15.2027	0.0795	0.1449		0.5747			16.0000	Dr. C. A. Göessmann.
Salina, New York.....	14.9443	0.0827	0.1316		0.5873			15.7480	Dr. C. A. Göessmann.
Great Salt Lake, Utah......	11.8623		1.4909		0.0858		1.5546	14.9941	Prof. O. D. Allen.
Bistineau Salt Works, La ..	8.450	0.234	0.102				0.144	8.930	Maurice Bird.
Bistineau Salt Works, La ...	7.810	0.301	0.156				0.113	8.379	Maurice Bird.
Pomeroy, Ohio..............	7.5531	1.371	0.5799	0.0092				9.528	W. J. Root.
Canal Dover, Ohio...........	7.490	1.949	0.761	0.0282				10.455	W. J. Root.
Charleston, West Virginia...	7.3094	1.5162	0.3744					9.2000	G. H. Cook.
Saltsburg, Pa...............	7.1320	1.5726	0.3986					9.1115	George J. Poepplein.
King's Salt Works La......	6.940	0.1520	0.135		0.010		0.213	7.450	Maurice Bird.
Drake's Salt Works, La.....	5.580	0.303	0.135				0.142	6.160	Maurice Bird.
Drake's Salt Works, La......	5.440	0.356	0.159				0.085	6.040	Maurice Bird.
Rayburn's Salt Works, La .	4.60				0.322	0.029		5.064	Maurice Bird.
Price's Salt Works, La......	3.14	0.079	0.138				0.080	3.437	Maurice Bird.
Sea water................ ...	2.700		0.360		0.014	0.228		3.53	Regnault.
Drake's Salt Works, La.—Artesian Well............	1.86		0.035		0.098+			2.00	E. W. Hilgard.

* Per cent.
† Brine made by dissolving rock salt. A saturated solution of Na Cl. according to Poggiale, contains 26.4 per cent of solid matter.

TABLE II.—ANALYSES OF TOTAL SOLIDS IN BRINES OF THE UNITED STATES

Localities.	Sodium chloride.	Calcium chloride.	Magnesium chloride.	Calcium sulphate.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
Saltville, Smyth Co., Va	98.37*	——	——	1.22
Manistee, Mich	97.00	1.31		1.68
Syracuse, New York	95.03	0.49	0.89	3.55
Geddes, New York	95.01	0.49	0.90	3.59
Salina, New York	94.89	0.52	0.83	3 73
Bistineau Salt Works, La	94.64	2.62	1.14	——
Bistineau Salt Works, La	93.82	3.60	1.87	——
King's Salt Works, La	93.14	2.04	1.81	0.14
Price's Salt Works, La	91.36	2.30	4.02	1.45
Drake's Salt Works, La	91.24	3.43	2.64	——
Rayburn's Salt Works, La	90.83	——	——	6.36
Drake's Salt Works, La	90.56	4.92	2.09	——
Drake's Salt Works, La	90.09	5.90	2.63	——
Banks, Bay Co., Mich	82.23	12.26	5.22	0.29
Saginaw, Mich	81.35	9.72	6.91	0.52
Charleston, West Va	79.45	16.47	4.07	——
Pomeroy, Ohio	79.27	14.39	6.09	——
Great Salt Lake, Utah	79.13	——	9.94	0.57
Port Austin, Mich	78.91	14.01	7.02	0.05
Saltsburg, Pa	78.26	17.26	4.37	——
Sea Water	76.49	——	10.20	3.97
East Saginaw, Mich	76.14	14.83	8.01	0.44
Canal Dover, Ohio	71.64	18.66	9.28	——

* Per cent of total solids.

Dauchite might furnish water transportation for the Bistineau product part of the year but could hardly be depended upon.

Salt from Bistineau and King's would have to meet the competition of the salt made from the rock salt brines of Grand Saline, Texas, and Belle Isle, Louisiana, and the ground rock salt from the Avery island mines as well as salt which may be made at other of the Five Islands or the recently discovered salt beds at Anse la Butte, St. Martin's parish, La., and Damon's Mound, Brazoria Co., Texas. The Soloman City, Kansas, works have been able to continue operations though surrounded by works using rock salt brine and the West Virginia and Ohio salt works have increased in size, notwithstanding the nearness of the stronger New York and Michigan brines. Perhaps similar careful management would meet with the same happy results in this state.

While the known brines at Rayburn's, Drake's and Price's can hardly be regarded as commercially valuable it is not at all impossible that salt or brine may be found in these places in quantity and quality to render its exploitation profitable nor is it improbable that stronger brines will be found at Bistineau and King's. The extreme similarity of the geological structure of these domes in northern Louisiana to the domes which contain salt, sulphur and oil farther south makes us feel that deep holes at these places are more likely to yield profitable returns than similar holes any place else in the northern part of the state.

GEOLOGICAL CONSIDERATIONS

Resumé

It has been shown that the principal brine springs in northern Louisiana are to be regarded as Cretaceous outcrops. At Rayburn's, Bistineau and King's fossils characteristic of the upper beds of the Upper Cretaceous have been found.* At Rayburn's beds of gypsum and a porous, banded, crystalline limestone, similar to that found at Winnfield and Bayou Chicot occurs beneath the highly fossiliferous Cretaceous limestone. While proof is lacking of the Cretaceous age of the hard leaf-bearing, sandy, pyritic limestone which occurs at Coochie brake and Price's, and which at Drake's seems to be associated with a large bed of soft chalk-like limestone, the facts thus far collected indicate it rather strongly.

Dome structure.—The dome structure of these and other north Louisiana Cretaceous outcrops, notably Winnfield and Coochie brake, is attested by a number of facts; no one of which is entirely conclusive but which, when taken together, have a cumulative value:

(1)—All the dips, which have thus far been observed support this conception of their structure. At both Winnfield and Coochie brake it is possible to obtain enough dip observations to

* Apparently the equivalent of Hill and Vaughan's Webberville beds of Texas and of the Ripley Cretaceous of Mississippi.

show clearly the major part of a dome. The dip observations at Drake's and Price's, while not conclusive, add their mite to the general evidence.

(2)—The presence of islands of Cretaceous limestone surrounded by upper Eocene deposit is itself indicative either of domes or butte-like erosion remnants.

(3)—The evidence furnished by the deep wells of the region is meagre but, so far as it goes, it is conclusive. At Shreveport a well over 1000 feet deep showed no Midway or Cretaceous limestone. A well at Natchitoches, 600 feet deep, did not pass through the Lignitic, and the well at Colfax, over 1,000 feet deep, does not appear to have reached the Cretaceous.

(4)—The arrangement of the wells on the old salines, either in a single group as at Rayburn's, suggesting the top of a dome, or in a circle as at Bistineau, Drake's and Price's, suggesting an eroded dome with the wells following approximately the outcrop of the brine bearing strata, corroborates this idea.

The Lick hill at Price's will furnish further evidence if it is proved that it is composed of limestone as the sink holes upon it seem to indicate.

RELATIONS TO SURROUNDING REGIONS

Similar domes in Louisiana and Texas.—The accompanying map, Plate XXIII, shows the location of points in Louisiana and Texas where strikingly similar phenomena have been observed.

At Bayou Chicot there are two small outcrops of banded crystalline limestone very similar to the Winnfield limestone. These outcrops show extravagant dips and are surrounded by beds of upper Grand Gulf age.

The Five Islands were discussed at length in a former report* and it was shown that at Belle Isle there is a distinct dome. At Côte Carline and Grand Côte there are highly elevated, partially eroded dome-like masses of rock salt, surrounded on all sides by deposits of recent age at least a thousand feet thick. At Petite Anse the limit of the flexibility of the salt was reached and a fault block resulted. The contour of the salt and its relation to

* Geol. Surv. of La. 1899, pp. 210–262.

the surrounding country suggests that this may be a fault associated with a dome. This explanation seems more in accordance with the structure at similar localities where the data is more complete. Moreover a fractured, steep-sided dome is more probable than the needle-shaped fault block which the fault block theory, without modification, would necessitate.

Recent borings at Anse la Butte, St. Martin's parish, La., have revealed large beds of rock-salt at a depth of 391 feet. The well sections here are very similar to those at Belle Isle; and have furthermore shown the galena crystals of the upper Belle Isle section. Deep wells nearby have failed to find the salt layer and we are inclined to regard the structure here as very similar to that at Belle Isle.

Numerous drill holes have established the sharp dome shape, of the Sulphur City and Beaumont deposits, and we feel that the quaquaversal nature of the structure at those places is established. The oil-bearing rock at Beaumont is a pure,* porous, banded, crystalline limestone apparently identical with the Winnfield limestone.

Big Hill, High Island and Damon's Mound are the Texas representatives of the Five Islands, of which they are the topographic counterparts. Damon's Mound furnishes a very suggestive mass of data: it is a rounded hill mass, about two miles in diameter, with a maximum elevation of about 75 feet above the plain at its base. Its rounded topographic aspect seems to be due to the manteling of an eroded dome with Lafayette sand and gravel, and Port Hudson loam. On the eastern side of the mound, and 50 feet above the plain, is an outcrop of banded, white and grey, porous, crystalline limestone. The outcrop is at present covered with the water of a pond but judging from the reports of residents, who worked in the limestone when it was quarried for lime-burning, and from the record of the Damon Mound Oil Company's well, east of this outcrop, the limestone dips away from the hill at a considerable angle. West of this outcrop, and

* An examination of the oil-bearing rock from a depth of 1025 feet in Higgins Oil Company's well No. 2 by Dr. A. C. Gill reveals less than 1 per cent of material other than $CaCO_3$. This material is for the most part gypsum with a little silica. A qualitative test for magnesium showed only a trace.

so stratigraphically below it, the Herndon well has shown:* (1) 171 feet of sand and clays of uncertain age, probably comparatively recent, containing shells of the genera† *Physa*, *Amnicola*, *Planorbis* and a few fragments of *Gnathodon*; (2) 379 feet of gypsum and anhydrite; (3) 30 feet of porous gypseous material containing sulphur. (Water from this layer is charged with H_2S and SO_2 and rises to within 70 feet of the surface.) (4) soft anhydrite 8 feet; (5) 600 feet of salt with anhydrite layers from 830 to 900 feet and from 1160 to 1180. Wells on the western side of the mound show over a thousand feet of material which cannot be regarded as older than late Tertiary.

This section combines in a very remarkable way the salt of the Five Islands, the porous sulphur bearing gypsum of Sulphur City and the porous limestone of Beaumont, Bayou Chicot, Winnfield, and Rayburn's, and does much to strengthen the evidence of the stratigraphic unity of these domes.

In northeastern Texas there are three Cretaceous islands which seem to be in every way the counterparts of those in northern Louisiana. At two of these the same fauna shown in the north Louisiana salines has been found.

The extreme similarity of the geological structure of these different localities is evident and we feel that the evidence thus far collected points very strongly to a common geological age and that we are justified in referring them all to the Cretaceous.

Time of formation of the domes.—Whatever the forces, or the causes of the forces, which produced these peculiar quaquaversals, the absence of Midway deposits from all save King's and the Many dome indicates that at the beginning of the Eocene they were either islands in the Tertiary sea or that they were so slightly submerged that the vaneer of deposits they received was readily eroded in the following periods.

The movement thus begun in the Cretaceous seems to have continued intermittently to the present time. On Belle Isle a bed containing shells common in the gulf to-day is inclined at

* This section will be given more in detail in a forthcoming U. S. Survey Bulletin by Dr. C. W. Hayes.

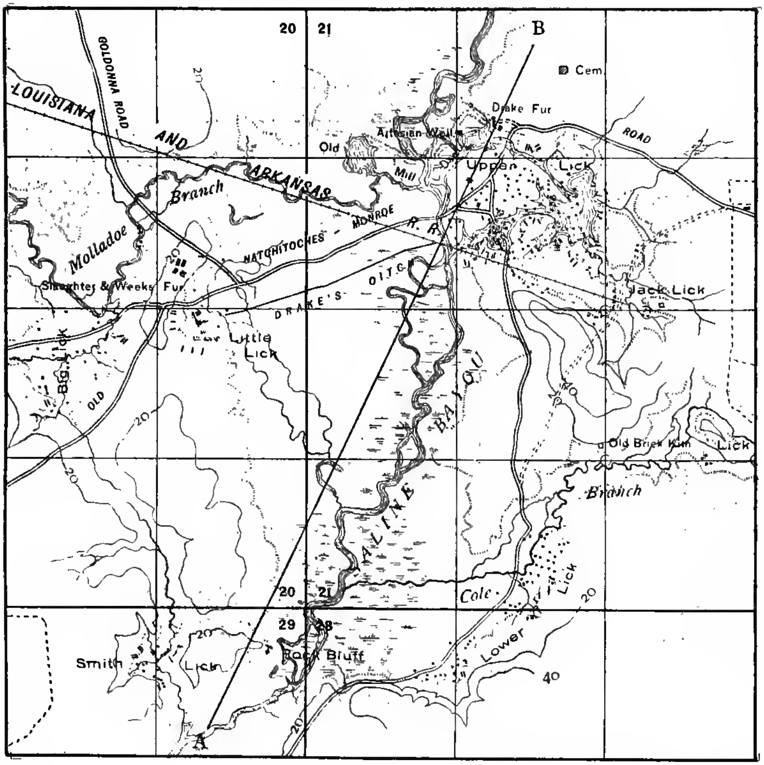
† These gastropods are regarded by Harris as identical with species common in the Erie canal to-day.

an angle of 23°. The outcrop at Winnfield shows evidence of movement after the deposition of the Lower Claiborne Eocene.

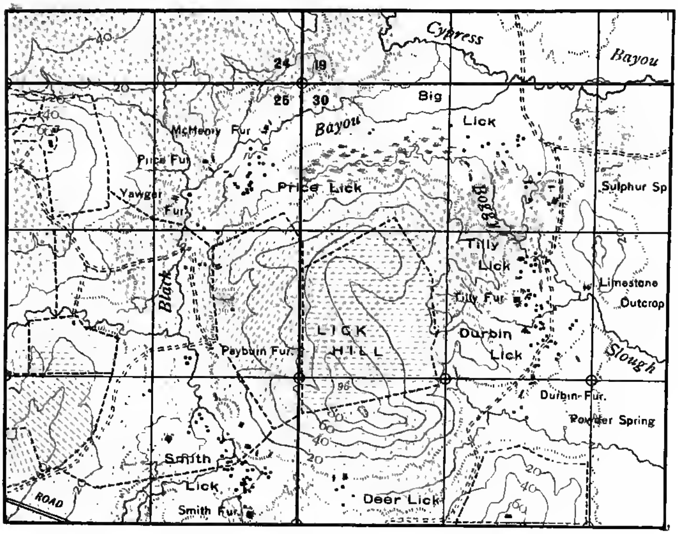
All the domes in the southern part of Louisiana and Texas, save one near Sour lake (where Harris has just found Jackson fossils at a depth of 1500 feet while a nearby well does not pass through the late Tertiary at a depth of 2000), either maintained their island like character till the late Pliocene or have been so subjected to erosion that all trace of deposits of pre-Pliocene age are lacking.

Standing at different heights, differently protected by the sediments of succeeding periods and varying in the rate of their elevation, the different domes naturally show all degrees of dissection. The low lying dome at Beaumont shows sign of relatively little erosion while the more elevated ones at Damon's and the Five Islands have been very considerably eroded. The denudation on the western three of the Five Islands seems to have been particularly great. At Drake's and Bistineau erosion has progressed to such an extent that the topographic aspect of the domes has been entirely destroyed.

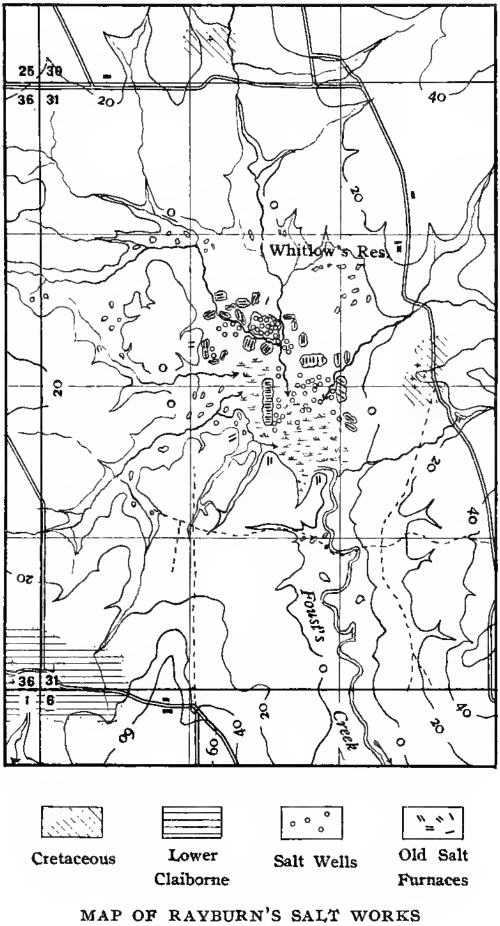
Lines of weakness.—Whether these domes have any connection one with another or whether they are entirely independent remains to be proven. Certain lines of weakness have been established and these have a northeast-southwest axis. The Coochie brake-Winnfield outcrops are points of maximum elevation on an anticlinal. At Coochie brake there is evidence of faulting in addition to folding. There is some evidence of a low anticlinal developing, at present, across the Angelina and Sabine rivers (see article on the Sabine river) with an axis very nearly parallel to this axis and more or less parallel to the line of the Balcones faulting. What connections other of the domes may have with each other is purely conjectural. (See Plate XXIII.)



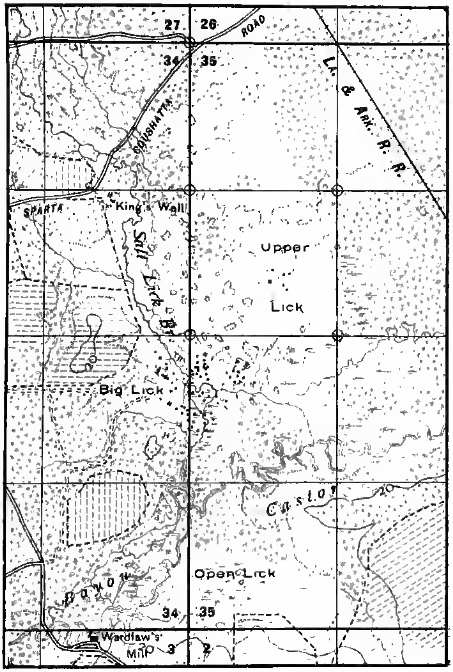
MAP OF DRAKE'S SALT WORKS
BY A. C. VEATCH



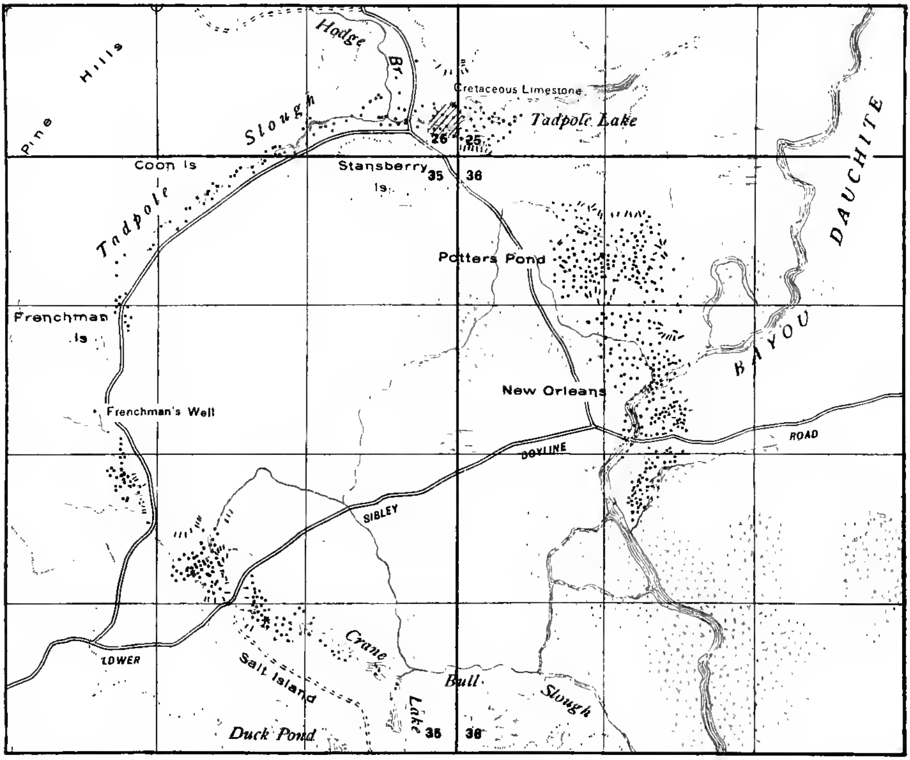
MAP OF PRICE'S SALT WORKS
BY A. C. VEATCH



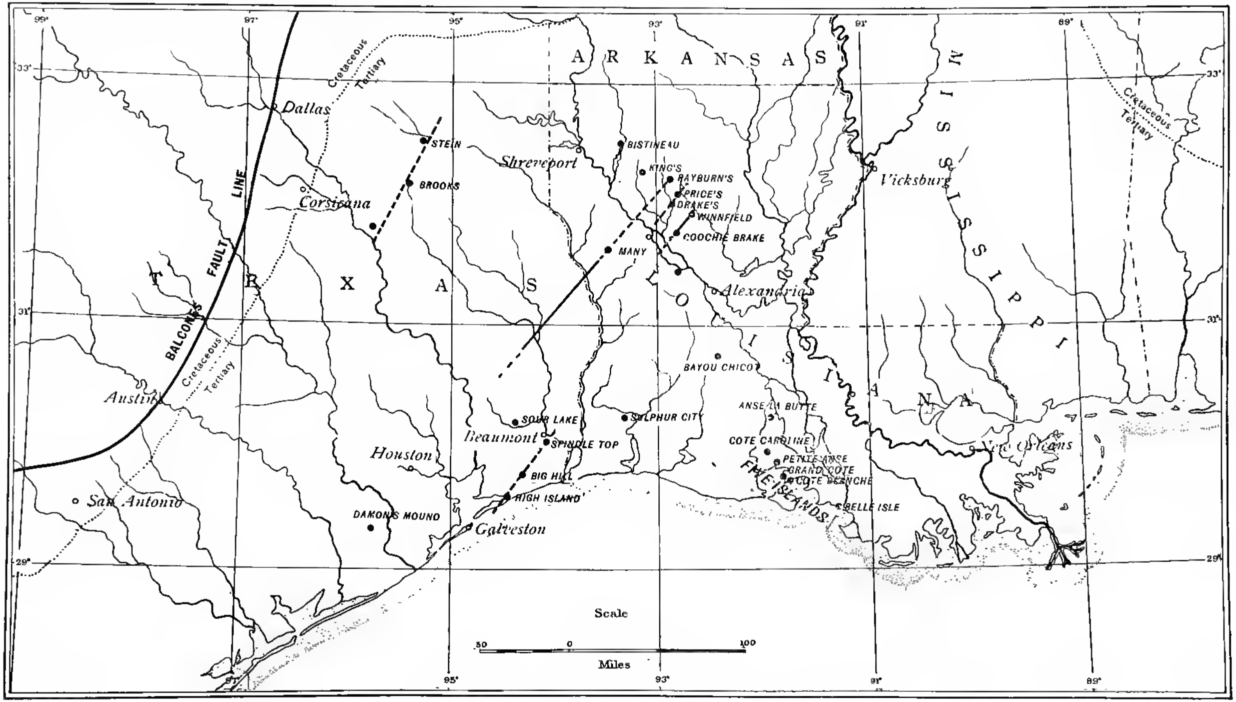
MAP OF RAYBURN'S SALT WORKS
BY A. C. VEATCH



MAP OF KING'S SALT WORKS
BY A. C. VEATCH



MAP OF BISTINEAU SALT WORKS
BY A. C. VEATCH



MAP OF DOMES OF LOUISIANA AND TEXAS

SPECIAL REPORT
No. III

THE GEOGRAPHY AND GEOLOGY OF THE SABINE RIVER

BY

A. C. VEATCH

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THE GEOGRAPHY AND GEOLOGY OF THE SABINE RIVER

GEOGRAPHY AND PHYSIOGRAPHY

GEOGRAPHY

Cartography

Early maps of the Sabine river.—The information in our possession at present will hardly justify an attempt at a detailed cartographical history of the Sabine river. The probable date of its first appearance on the maps of the early Spanish and French cartographers, its various vicissitudes at their hands and at the hands of other continental cartographers and all that interests a student of the cartographical lore and history of a river it is hoped will some day form a part of a general discussion on the cartography of Louisiana.

After the period when the river was represented as a mere, more or less, wavy line in a position which gradually became more and more nearly a correct approximation, came definite attempts to locate the river and delineate its meanderings.

Darby (1812–1813).—We owe our first correct idea of the general shape and location of the river to William Darby. In 1812 and 1813 he ran a traverse line from Fort Claiborne at Natchitoches to the Sabine river, thence down the river to its mouth, thence along the shore of the gulf and up Calcasieu river to about the position of Lake Charles.* On his map of Louisiana† there is apparently no attempt made to show the shape of any of the bends of the river, it being represented merely by the con-

*Notes in Regard to my Survey of Sabine river Hist. Mag. (Dawson's) vol. 12, p. 223, 1867.

†A map of the State of Louisiana with part of the Mississippi Territory from Actual Survey by Wm. Darby, Phila. 1816. The location of his line from Natchitoches to the Sabine river is shown on this map. This map together with most of the articles referred to in this paper will be found in the Howard Memorial Library at New Orleans. Thanks are due to Mr. Beer, the librarian, for many courtesies.

ventional wavy line. This map is the source from which map compilers drew their information for many years.

Eaton (1837).—The growing importance of the river as the boundary between the United States and Texas; the requests of the people along the river to the government to open the river to navigation by the removal of the raft and the question of the cheapest route for supplies to Camp Sabine caused the war department to direct Maj. W. G. Belknap to examine the river and if possible remove the raft.* He reports the raft removed and the river open to navigation in 1838 and transmits with his report† a map of the river from Sabine pass to Sabinetown by Lieut. J. H. Eaton.‡ This map shows the shape of the bends in the river with considerable exactness.

United States-Texas Boundary Survey (1840–1841).—The map‖ which accompanies the report§ of this survey seems to be Eaton's map with a number of additions and corrections. No attempt to meander the river appears to have been made and the map seems to have been constructed by plotting Eaton's survey on the longitude and latitude net obtained by their observations, together with what corrections and additions they could make to the detail of the older map by sketching from the deck of their

* This raft seems to have been situated between Belgrade and the mouth of Bayou Anacoco.

† Obstructions in Sabine river; 25th Cong. 2d Ses. House Ex. Doc. vol. 10, No. 365, 1838.

‡ Sketch of the Sabine River, Lake and Pass from Camp Sabine to the Gulf, a Distance of 300 miles by Lieut. J. H. Eaton, 3d U. S. Infantry. Scale 4 miles to an inch; 25th Cong., 2d Ses., House Ex. Doc., vol. 10, No. 365, 1838.

‖ Map of the Sabine river from its mouth on the Gulf of Mexico in the sea to Logan's ferry in Latitude 31° 58′ 24″ north showing the Boundary between the United States and the Republic of Texas between said points, as marked and laid down by Survey in 1840 under the direction of the Commissioners appointed for that purpose under the first Article of the Convention signed at Washington Apr. 25, 1838. Surveyed in 1840 by (on the part of the United States) J. D. Graham, Major, U. S. Topog. Eng.; Thomas J. Lee, First Lieut., U. S. Topog. Eng.; George G. Meade, C. E.; (on the part of Texas) P. J. Pillans, Eng.; D. C. Wilber, Sur.; A. A. Gray, Asst. Eng. Drawn by Lieut. T. J. Lee, 1842.

§ 27th Cong. 2d Sess. House. Ex. Doc., vol. 2, 78 pp.; also 27th Cong. Sen. Ex. Doc., vol. 3, No. 199, with map. 1842.

steamboat. This map compares very favorably with the results of the Polhemus survey and remains to this day the most accurate map of the river published. The compilers of the maps of the state have without exception overlooked this source of information.

Public land surveys (1830–1879).—The work of the surveyors of the U. S. Land office in the townships along the Sabine river have given us a series of maps of the river of varying degrees of accuracy. In the early thirties a few townships about the base line and a few below Logansport were completed and in the succeeding years the townships between were filled in. The part of the river between Anacoco and the Narrows was not surveyed till 1879, and it was the following year before the maps appeared. Lockett's map,* published in 1873, is for the most part based on these surveys, and therefore shows no detail whatever between Anacoco and the Narrows. Hardee's map† (1895) appears to have been hastily drawn and no attempt was made, along the Sabine river, to carefully plot even the land office maps which would have given a much better result than he has obtained. He has followed Lockett in the incorrect location of Nix's ferry, and has incorrectly located Eave's Plantation (which is the same as Nix's ferry) and Hanly's Point.

Leavenworth (1872–1873).—In 1872–1873 F. P. Leavenworth, Asst. U. S. E., made a reconnaissance of the river beginning at Belzoria, Texas. His map,‡ plotted on a scale of an inch to two

* The Louisiana State University Topographical Map of Louisiana showing the Characteristic Features of the Surface of the State in symbols and and colors, compiled from the latest and most authentic sources with many additions and corrections from actual reconnaissance by S. H. Lockett. Scale 1 in. = 10 mi. New York, 1873.

† Hardee's New Geographical, Historical and Statistical Official Map of Louisiana Embracing Portions of Arkansas, Alabama, Mississippi and Texas from Recent Government, State, Parish, Railroad and Private Surveys and Personal Investigations and Officially Compiled under authority from the State Legislature by William J. Hardee, Civil Engineer. Scale 1 in.=6 mi. Chicago, A. D. 1895.

‡ A map of the Sabine river from its mouth to Belzoria, Texas, by F. P. Leavenworth. Scale 1 in.=2 mi. Oct. 1, 1872, to Apr. 5, 1873. MSS. in archives of the War Department. Leavenworth's report will be found in An. Rept. Chief of Eng., 1873, p. 681–683; also 43d Cong. 1st. Sess., House Ex. Doc., vol. 2, p. 681–683, 1874.

miles appear to have been compiled in part from the land office maps, and was evidently not considered sufficiently trustworthy for in a few years a second survey was ordered.

Polhemus (1878).—This survey extended to Hamilton, Texas, and though of a reconnaissance nature, made with a Gurley transit and stadia, was done with so much topographic skill and fidelity to detail that it is an extremely satisfactory map. This map* has unfortunately never been published, and it is through the courtesy of the Chief of Engineers that Mr. Pacheco, of this survey, was allowed to make tracings of it as well as the preceeding map.

Construction of map accompanying this report.—In the construction of this map the latitude observations of the United States-Texas Boundary Commission have been assumed as correct. The longitude correction has been found by comparing the longitude of Mound A, Sabine pass with the location of the same point on the U. S. Coast and Geodetic Survey Chart No. 203.

Longitude Mound A Sabine Pass

By calculation U. S. C. S. Chart 203	93° 51′ 03″
By observation, U. S.—Tex. Boundary Survey..	93° 50′ 14″
Correction..	49″

A check on this longitude correction is found by comparing the longitude of the state line as found by calculation from the maps of the boundary survey and the longitude of the Arkansas-Texas line as determined by the Coast Survey at Texarkana.

Longitude Louisiana-Texas Meridional Boundary

By observation U. S. Coast Survey at Texarkana..	94° 02′ 34.1″
By calculation U. S.—Texas Boundary Survey map	94° 02′ 18 ″
Correction..	16.1″

* A map of the Sabine river from East Hamilton to Sabine lake, Twelve sheets, Scale 1:5000, by J. H. Polhemus. Sept. 29 to Dec. 8, 1879. MSS. in archives of the War Department. Polhemus' report will be found in the An. Rept. Chief of Eng. for 1880, vol. 2, pp. 1195–1199, 1881; also 46th Cong., 3d Sess., House Ex. Doc., vol. 4, pp. 1195–1199, 1881.

Upon the longitude and latitude net thus obtained the Polhemus survey from Sabine lake to Hamilton and the Leavenworth survey from Hamilton to the state line have been projected. Sabine lake and soundings have been added from Eaton's map and Sabine pass and the coast line from Chart No. 203 U. S. Coast and Geodetic survey and from Brownlee's 1899 survey.*

DESCRIPTION

The river.—From Logansport the Sabine river flows in a general southeasterly direction half the distance to the sea, it then flows southwest and finally enters the gulf, by way of Sabine lake and Sabine pass, at a point a trifle east of south of the point where it enters Louisiana. The river is for the most part a rather swift stream flowing in a narrow sinuous channel, with one sharp bend following another in quick succession, a sandbar on one side and a rapidly caving bank on the other. Sometimes there are long stretches of slow moving water with gently sloping banks on either side covered with overhanging trees. The most pronounced of these reaches are: near Logansport, just below Myrick's ferry, below Hamilton, Pendleton and Robinson's ferry. Above Myrick's ferry the river is between 80 and 100 feet wide, and tall trees falling sometimes reach from bank to bank. In the reaches a width of perhaps 150 feet is attained but the average width down to Belgrade is about 100 feet. From Belgrade to the Narrows the average width is perhaps 200 feet with an extreme width in a few places of 400 feet or more. At the Narrows the river is contracted to half the width above. Below the Narrows it widens to 300 feet and attains a width of 500 feet at Orange and a 1000 feet near Sabine lake. The height of the river banks is 30 feet about Logansport and decreases gradually to a few feet at the Narrows and almost nothing at Sabine lake. The bottom land varies from two to six miles in width.

The bluffs.—Here and there the river strikes the hills bordering the valley forming bluffs which, in the upper part of the region under discussion, are often over a 100 feet high. These bluffs appear to be of two types:

*An. Rept. Chief of Eng. for 1899 (opp. p. 1861), 1890.

(1) Hill bluffs. Bluffs formed by the denudation of rolling hill land areas. The eroded land surface shows in cross section and the crests of these bluffs are therefore generally serrated. They are generally high and are composed for the most part of Eocene and Oligocene material.

(2) Flat-topped bluffs.—Low bluffs with flat tops but little higher than the surrounding bottom lands. In height they are "bluffs" only by courtesy but in the lower river they are sharply separated from the surrounding bottom land by their covering of pine and, though but a few feet high, are rather marked topographic features. These bluffs are composed of bright colored sauds or clayey sands, often containing some gravel, which appear to grade laterally into material not sharply separated from the recent river silt. In the upper river these bluffs often show near low water line a few feet of old Tertiary clay. A number of these have been represented on the map by a single line of hachures and make the valley of the river appear narrower than it really is.

The shoals.—In a number of places between Logansport and Burr's ferry a rocky ledge or a ledge of very hard clay passes partly across the river, near low water line, confining the river to half its normal width and causing a considerable acceleration of the current. When these ledges pass entirely across the river, as they do in several places, a rapids is formed. The two most pronounced of these rapids are McClanahan Shoals at the mouth of Bayou Negreet and Goodwins Shoals at Columbus (see Plates XXIV, XXVI and XXXIII and Figs. 12 and 13).

Distances along the river.—On the distance from Logansport to the sea there is considerable variation in published accounts. Brackenridge* (Darby's estimate) states it as 400 miles; Overton† estimates it at 600 miles; Williams‡ at 400 and each succeeding estimate has made it less. Among the people along the river there is a tendency to overestimate the distance. At Logansport estimates run from 500-900 miles and as far down as Burr's ferry an estimate of 300 miles was heard.

* Views of La. p. 53, Pitts., 1814.

† 27th Cong. 2d Sess. House Ex. Doc. No. 51, vol. 2, p. 64, 1842.

‡ An. Rept. of State Eng. for 1848, p. 11, N. O. 1848.

GOODWIN'S SHOALS, NEAR COLUMBUS, LOOKING DOWN THE RIVER

The following table is based upon measurements made on Polhemus' map from Sabine lake to Hamilton and on Leavenworth's map from Hamilton to Logansport.

Table of Distances along Sabine River.

	Miles
End of Jetties	0.0
West Pass, Sabine river	25.3
Adams bayou	31.1
Orange	36.3
S. P. R. R. bridge	47.3
Lower end of Narrows	48.2
Niblett's bluff	51.0
Pruit's bluff	53.3
Morgan's bluff	54.4
Head of Narrows	65.1
K. C. P. & G. R. R. bridge	66.4
Mill bluff (Deweyville)	70.7
Sudduth's bluff	83.0
Nix's ferry	97.0
Salem ferry	110.6
Whitman's ferry	117.0
Belgrade	121.1
Upper Belgrade	122.0
Stark's ferry	132.7
Clark's warehouse	156.1
Droddy landing	159.8
Knight's landing	162.1
New Columbia	168.2
Burr's ferry	183 0
Hattan's ferry	198.2
Schnell's landing	203.3
Anthony's ferry	204.9
Robinson's ferry	214.5
Columbus	224.1
Sabinetown	232.3
Pendleton	238.2
Carter's ferry	244.0

Moran's landing	250.6
Chambers' ferry	256.3
Hamilton	260.7
Myrick's ferry	281.2
Logansport	315.0

PHYSIOGRAPHY

THE SHOALS

Description.—Perhaps the most interesting physiographic feature of the river, in this region, is the shoals or rapids. Here in a flat bottomed, silted up valley, two to five miles wide, in a region which has long been considered one in which a rather rapid subsidence is taking place, we find a meandering river superimposed on ledges of the country rock with resulting shoals and rapids that extend along its course for a distance of sixty miles (see Plate XXXIII).

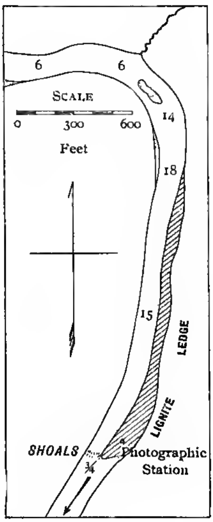

FIG. 10.—SKETCH MAP OF SHOALS AT STONE COAL BLUFF. (AFTER POLHEMUS.)

In only two cases, at Sabinetown and Columbus, are these ledges associated with high bluffs, generally they appear near water level under a bank of light colored sands or silty clays of about the same height as the ordinary banks of the river. The prevailing type is well shown at Stone Coal "bluff," of which a sketch map is shown in Fig. 10. The term bluff is a misnomer, for the bank here is but a few feet higher than the ordinary banks. It is composed of gray sands and clays similar to those which occur in all the high banks along the river. The relation of the ledge, which in this case is of lignite, to the bed and banks of the river is shown in Figs. 10 and 11. The comparative cross-sections give a good idea of the river at the shoals and just above. One would expect from the depth of the water on the crest of the shoal, about three-fourths of a foot at

SHOALS AT STONE COAL BLUFF

low water, something more of a surface disturbance than is shown in Plate XXIV which was taken when the water was about two feet above its lowest stage.

Substitute in this description a hard lignitic clay with calcareous concretions for lignite and you have the shoals at the mouth of La Nana bayou and at Carter's ferry. Below Anthony's ferry the ledges are of Grand Gulf sandstone.

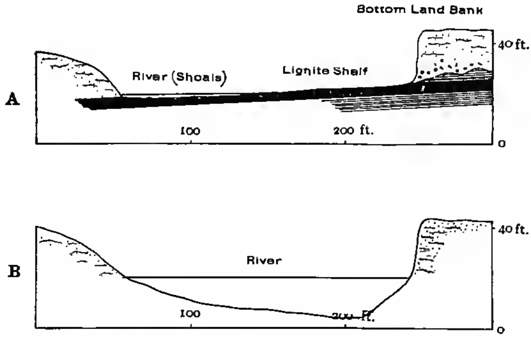

FIG. 11.—COMPARATIVE CROSS SECTIONS OF THE SABINE RIVER AT STONE COAL BLUFF. A—AT SHOALS. B—ABOVE SHOALS.

McClanahan shoals.—One of the worst shoals on the river is shown in Fig. 12. It is about a quarter of a mile long and in low water is quiet dangerous for even small boats, as the writer has reason to remember. The ledges are of hard Lower Claiborne limestone and one passes almost across the river just above the mouth of Low's creek, where Polhemus reported 6 inches of water when the river above showed a depth of 18 feet. The island just below, near the mouth of Bayou Negreet, is composed of coarse ferruginous conglomerate.

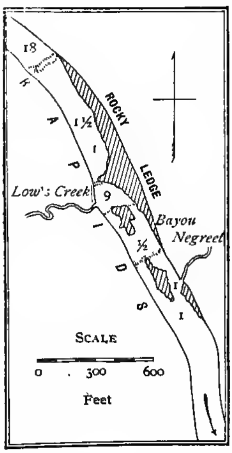

FIG. 12.—SKETCH MAP OF MC CLANAHAN SHOALS. (AFTER POLHEMUS.)

Goodwin's shoals.—Near Columbus is perhaps the most extensive shoals on the river. The first of the Columbus series is about half a mile above the village; the second shows just above the old ferry (see Fig. 13). Below the ferry a series of rocky islands

extend along the river for a quarter of a mile. These combine with the rocky shelves of hard blue Lower Claiborne clay on the shore to produce the rapids known as Goodwin's shoals. Plate XXIV shows a view of the lower rapids looking down the river from about half way up the side of the Columbus bluff. Plate XXVI is a nearer view of the upper crest.

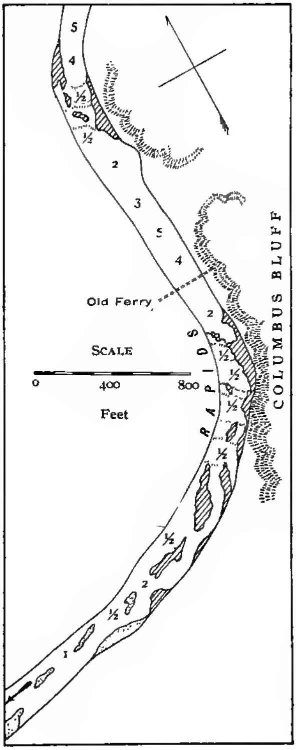

FIG. 13.—SKETCH MAP OF GOODWIN'S SHOALS, NEAR COLUMBUS, LA. (AFTER POLHEMUS.)

No accurate levels have ever been obtained at any of these rapids but conservative estimate would make the fall at Goodwin's from 4 to 5 feet in a quarter of a mile.

Theories of origin.—The nature of the material which covers many of these ledges and which lies unconformably on the older material in the high bluffs as well as in the bottoms suggests a possible origin for these rapids but the complexity of these bottom deposits and the difficulty of arriving at any satisfactory conclusions regarding them makes us hesitate about entirely accepting it. Beds of sand, often brightly colored and sometimes containing chert and quartz pebbles, cover many of these ledges and most of the higher bluffs. In the bottoms the deposits are very nearly of the same height as the surrounding flat lands; they appear to pass both horizontally and vertically into brown silty clays mottled with red, such clays as one would naturally regard as of recent river origin: if they be not of recent origin, the recent river deposits are restricted to the sand bars and to a veneer of sediment deposited in flood time and the most of the valley deposits are to be regarded as the valley equivalents of the upper part of the coastal section. In other words here is a valley which, in

UPPER PART OF GOODWIN'S SHOALS NEAR COLUMBUS

company with all the valleys of the coastal region, received a certain amount of sediment during the last general subsidence of the coastal plain. The deposits were more or less irregular and on re-elevation the river naturally sought the lowest place in the valley. This new channel did not entirely coincide with the old and the river in cutting out its channel found itself superimposed on projecting ledges of older clays which had resisted erosion in the former period. The common height of the ledges and frequency with which they are exposed by the river suggests something of an old base level in which case the river is to be regarded as having now reached and passed that base level.

While such a hypothesis covers some of the facts observed it leaves some entirely unexplained. It does not explain why the largest rapids should be at Columbus except by accident. These rapids can hardly be regarded as the limit of the wearing back of the rapids for in such a case the ledges on the lower part of the river should stand higher above the level of the water than those above Columbus and such is not the case.

Such a theory requires that the other valleys of the same region should show analogous phenomena. The rapids at Alexandria on Red river and Catahoula shoals on the Ouachita while evidencing rather recent topographic changes at those localities can hardly be regarded as entirely analogous. The Angelina-Neches river system seems to offer more in common, and to be a good stream on which to check our results from the Sabine. Observations on this river from the headwaters to the gulf seem to justify the conclusion that the Sabine did receive considerable silt during the Lafayette and Port Hudson submergences, and that the pine-clad, flat-topped, low-lying, red sand bluffs represent the erosion fragments of this or these depositions. The bulk of the information collected on the Angelina-Neches is, however, much in favor of a theory of crustal distortion to account for these rapids.

Apropos a theory of orogenic movement, unmodified, to account for these rapids the following facts may be regarded as significant: The largest rapids on the Sabine occur at a point where the dip changes abruptly from southwest to southeast; a line connecting this point, the Many dome and the point of

maximum erosion on the Angelina river is parallel to the known axis of the Winnfield Coochie brake disturbance, and is more or less parallel to the line of the Balcones faulting. They suggest that there is here a low anticlinal which at the Sabine river is dipping with the axis of the fold. Such a theory would explain the distribution of the shoals up and down the river from the principal shoals or rapids.

As has been suggested the Angelina river throws some light on this question. The evidence here is purely topographical, but is of a much more pronounced character than that on the Sabine. Near the headwaters of the river, at a point about due east of Rusk, in Cherokee county, the banks of the Angelina are from 8 to 10 feet high. They rapidly decrease in height to a point six or seven miles above the H. E. & W. T. R. R. bridge where they are almost at water level. Many outlet sloughs leave the river and it has all the aspects of a stream at or below its base level. Just below the railroad bridge the river divides into many branches; narrow, tortuous, tree choked channels, which wander aimlessly through a great swamp and finally unite, several miles below, to form a low banked river. The banks now gradually increase in height and low, flat-topped bluffs, four to six feet high, composed of brightly colored sands, appear at intervals. Between the mouth of Ayrish bayou and old Bevilport the banks of the river are from 15 to 20 feet high, and the appearance of these bottom lands perched high above the river is in marked contrast to the flat swamp land at water level in the river valley above. The current in this portion of the river is quite swift and seems to reach its maximum velocity in the great southward loop two or three miles above Lewis ferry. From Bevilport to the gulf the banks of the river gradually decrease in height.

There appears then to be on the Angelina an area in which the river is engaged in rapidly wearing out its channel with a ponded area above, and this fact tends to corroborate the evidence offered by the Sabine of slight folding in this region. Whatever the cause, both the Sabine and the Angelina are now actively engaged in eroding their channels and have anything but the appearance of rivers in a region which is now subsiding.

THE NARROWS

Manner of formation.—Twenty miles above Orange the river enters what is known as the Narrows (see Plate XXXV). It is a narrow sinuous passage half the normal width of the river and seventeen miles long. To the east, is the old river obstructed with a raft several miles in length.

There can be little doubt but that the Narrows were formed, as suggested by Leavenworth, by the enlargement of a number of sloughs by water backed up by this raft. Such an action would be entirely analogous to the known action of the "great" raft in Red river and to the action of a raft in the upper part of the Sabine of which we have a historical account. In 1813 Darby found a raft between Belgrade and Stark's ferry of which he gives the following account: * "A few miles below the Alibama villages, the Sabine is encumbered with a raft of timber of a mile and a half in length. When the waters are high, an outlet from the right bank, leaving the river at the higher extremity of the raft, conducts into a small creek that enters the river below." This raft was removed by the war department in 1837 † but reformed before 1840 near Belgrade where the United States-Texas boundary survey found a raft two miles in length. ‡ A raft then formed just above Stark's ferry and in the early sixties succeeded in forcing the river to cut a narrow channel eleven miles long. §

Of the probable date of the formation of the Narrows we know little. This feature is not shown on Darby's map and no mention is made of it in his description. Whether it did not exist or whether he merely failed to observe it we do not know. The Narrows were formed at the time of Eaton's survey but the time that had elapsed since Darby's visit was quite sufficient for its formation.

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* A Geog. Des. of the State of La., etc. by Wm. Darby, Phila., 1816, p. 23.

† 25th Cong. 2d Sess., House Ex. Doc., vol. 10, No. 365, 1838.

‡ 27th Cong. 2d Sess., House Ex. Doc., vol. 2, No. 51, p. 66, 1842.

§ Polhemus gives the following account of this place: "Just above Stark's ferry the 'Raft' begins. It is that portion of the river some eleven miles in extent, formed about fifteen years ago by the opening up of a bayou or slough and its gradual enlargement as the original channel (or Old river) became choked with drift."

STRATIGRAPHY

INTRODUCTION

In Louisiana the lowest beds which have been recognized along the Sabine river are Lignitic Eocene. The succession of formations from the Lignitic to the Upper Oligocene is fairly complete. The Miocene has not yet been recognized and the exposures other than Eocene and Oligocene are of uncertain age, probably ranging from Pliocene to recent.

The following table gives the succession of formations and their probable thickness in this section :

Recent to Pliocene	Recent Alluvium Port Hudson Lafayette	?
Oligocene.............	Frio Clays (Chattahoochee). ..	200 ?
	Grand Gulf.................	1000
Eocene...............	Jackson......................	500
	Cocksfield Ferry Beds.........	450
	Lower Claiborne.............	550
	Lignitic	1000+

EOCENE

LIGNITIC

Preliminary remarks.—From Logansport to Hamilton the outcrops are for the most part small and rather unsatisfactory. No fossils were found in this part of the river and the two dips observed were on small outcrops and were contradictory. It is hence impossible to determine the exact stratigraphic relation of these outcrops to those occurring farther down the river and beyond the fact that these beds seem to be lower Lignitic and to lie below the Nanafalia or Gregg's landing beds at Pendleton nothing definite can be stated regarding them.

From Hamilton to the last outcrop of Lignitic near Sabinetown the exposures are much more numerous and satisfactory. Fossils occur well developed at two localities and it is possible to obtain enough reliable dip observations to learn something of the relative stratigraphic positions of the different outcrops. The general section of the river shown on Plate XXXVII begins at the Rock bluff above Chamber's ferry, the first good outcrop below

LOWER LIGNITIC EOCENE, HAMILTON BLUFF, TEXAS

Hamilton. A comparison of the dip observations will show that the dip from here to Bayou Negreet is about S. 20° W., 1:60, and I have used this dip except where very pronounced local evidence indicated that it should be slightly modified.

Outcrops from Logansport to Hamilton.—At Logansport 3 to 4 feet of dark sandy clays, with limestone concretions, overlaid with light colored, ironstained sandy clay is exposed in a small bluff near the railroad bridge.

A few feet of lignitic clays are exposed near water level, beneath beds of light colored sands, at a number of points between Logansport and Hart's bluff, viz : at 1,2 and 4 Plate XXXII.

Hart's bluff at its upper end has an extreme height of about 60 feet above low water. Here the face of the bluff is much complicated with land slips and shows little besides a covering of light grey and yellow sandy clays containing rounded ferruginous gravel, and apparently identical with the bottom deposits into which they grade on the northern side of the bluff. At the lower end of the bluff the following section is shown :

Section at Hart's Bluff

		Feet	In.
1.	White and yellow sand	28	0
2.	Many colored chert and quartz pebbles with rolled pieces of petrified wood	0	6
3.	Lignite of good quality	0	9
4.	Finally laminated drab colored clay with lighter sand partings	1	0
5.	Sand	0	6
6.	Same as 4 containing at base, layer of light brown claystone concretions	3	0
7.	Finally stratified fine white sand	1	0
8.	Same as No. 4	11	0
	Water level.		

At 5, on the Louisiana side, there is a ledge of grey, concretionary, leaf-bearing limestone exposed at water level. A quarter of a mile below, a few limestone bowlders outcrop on the Texas side.

At 7, slightly below the DeSoto-Sabine parish line, a bed of lignite 3 feet thick is shown at water level. This is covered with 15 feet of bottom deposits. Dip here is N. 70° W., 1:100.

Section at Myrick's Ferry

		Feet.
1.	Unstratified grey and yellow sandy clay, red above. A few pebbles occur at the base and the clay weathers into pinnacles. This is the same as the material which caps Hart's bluff	22
2.	Very dark colored clay	3
3.	Grey sand	2
4.	Finely laminated dark clay with large calcareous concretions	22

The lower layers show a slight eastward dip, 1:100.

A few feet of lignitic clay show at water level at 10 on the Texas side of the river. By river two miles below this there is a bluff on the Texas side about 110 feet high.

Section at 11

		Feet.
1.	Unexposed to top of bluff	50
2.	Finely laminated dark lignitic clays with occasional concretions	60

Apparent fault near the middle of the bluff is due to a landslip.

Just above the town of Hamilton is a bluff 60 feet high. It shows 30 feet of dark laminated lignitic clays (see Plate XXVII).

Outcrops from Hamilton to Sabinetown.—About a mile and a half below Hamilton a line of high hills almost reach the river. No section is exposed, but large calcareous concretions show on the hillside.

At 12, a bluff about forty feet high shows a few feet of dark laminated clay with large calcareous concretions. The upper part of the bluff is grey and yellow sandy clay with small ferruginous gravel, apparently the same as the material in the banks of the river.

Section above Chamber's Ferry

(No. 13, Plate XXXIII)

		Feet.
1.	Unexposed	70
2.	Grey and light yellow slightly cross-bedded sand with large leaf-bearing calcareous concretion	56

Above Moran's landing there is a long line of bluffs slightly back from the water's edge. At 14 a little waterfall exposes the following section :

Section at 14

		Feet.
1.	Light yellow sand with fine clay partings	10
2.	Blue laminated sandy clay with *Venericardia planicosta*, *Anomia*, sp	8
3.	Covered to water level	20

Fossiliferous clay is exposed on a little point half a mile above Moran's and dip calculations show that it is the same as 2 of the above section. The ground was frozen so hard (February, 1900) that it was impossible to obtain any of these fossils in a condition in which they could be identified.

Ledges of lignitic clay appear at water level half a mile above Carter's old ferry and just below the mouth of LaNana bayou. There is the usual covering of sands and gravel.

A low pine clad bluff at 15 shows the following section :

Section at 15

		Feet.
1.	Slightly stratified white and yellow sand	20
2.	Yellow sand with chert and quartz pebbles and rolled pieces of silicified wood	2
3.	Dark blue to dirty yellow laminated sandy clay with calcareous concretions	4
	Water level.	

At Carter's ferry there is a small bluff showing about 15 feet of dark blue laminated unfossiliferous sandy clay. A ledge of limestone bowlders extends almost across the river just above the ferry. Below the ferry a 6-inch bed of lignite appears capping the clay. A second bed of calcareous concretions, stratigraphically about 30 feet above the first appears a few hundred

yards below the ferry. At the lignite bed the dip is S. 25° W. 1:50 but decreases to 1:70 at the second concretion bed.

Section near Mouth of Bayou Patroon

		Feet	In.
1.	Sands	12	0
2.	Lignite	0	9
3.	Covered	15	0
4.	Lignite	2	0
5.	Dark blue laminated clay	7	0

This outcrop shows a dip of 1:70 along the river which here flows southwest. The river bends southeast and the dip is still apparent though somewhat less. At Pendleton the bluff shows a slight westward dip. A connection of these various elements indicates a dip west of south of about 1:60.

The sections at Pine bluff and Pendleton were described at length in the report of this survey for 1899 and the fauna figured and described. The outcrop is regarded by Harris as about the horizon of the Nanafalia and Greggs' landing beds of the Alabama section.

A thin ledge of lignitic clay at 16 shows a decided westward dip.

In the bend above Stone Coal bluff a few feet of dark colored, laminated, sandy clay with small calcareous concretions shows beneath the usual covering of light colored sands and sandy clays with pebbles in the basal layers. This outcrop shows a dip a little west of south of 1:60.

A quarter below this outcrop the lignite ledge shows a dip of S. 30° W., 1:45. This lignite bed is about 3 feet thick and extends across the river forming a small shoals. About 200 yards south of this bed a second lignite bed shows a dip of about S. 45° W. 1:25. This bed exhibits a little distortion and several small folds make the exact determination of dip difficult. Dip observations seem to show that these lignite beds are the stratigraphic equivalents of the beds at the mouth of Patroon bayou.

Section at High Bluff

		Feet.
1.	Unexposed. Shows on surface chert and quartz gravel and large masses of conglomerate	25
2.	Laminated, drab to chocolate colored clays	20

LOWER LIGNITIC EOCENE, PENDLETON BLUFF, TEXAS

3.	Unexposed	25
4.	Crossbedded yellow sand with thin layers of white clay and lines of clay pebbles, the main lines of stratification corresponding to the general dip of the strata. In places the sands form large masses of ferruginous sandstone	44
5.	Irregularly bedded, dark-colored, lignitic, micaceous sandy clay containing large calcareous concretions	27

Dip about S. 15° W., 1:50.

About three-quarters of a mile above Sabinetown a ledge on the Louisiana side juts half way across the river. It shows 3 feet of greensand marl identical with the fossiliferous bed at Sabinetown. It is capped with grey calcareous concretions and the whole covered with pebble conglomerate. The concretions are exposed also on the Texas side, showing that the tertiary clay here forms the bed of the river.

The section at Sabinetown has been described in the report for 1899, page 67. Plate XXIX was taken from the west end of the bluff and shows the fossiliferous layers of this section. The best collecting is in this part of the outcrop and the fossils, as stated before, indicate a Woods bluff Lignite horizon. The river here is filled with rock masses which produce a small shoals.

At 18, the last outcrop of undoubted Lignitic material was seen. Here four feet of the fossiliferous greensand of the Sabinetown bluff section is exposed. It is overlaid with brown and chocolate colored laminated clay. The dip appears to be east 1:50.

The next outcrops below are the Low creek greensand beds.

Foster well.—Five and a half miles about due east of Stone Coal bluff Mr. D. M. Foster of Lake Charles is sinking a well in search of oil. In this well a 5-foot bed of lignite has been struck at 200 feet, above which there were clays and dark colored greensand marls to within 50 feet of the surface. Fossil shells were again encountered at 493 feet. This well is in a creek bottom but little above the level of the river bottoms and a dip of S. 20° W. 1:60. which seems to be the usual dip of this region, would lead us to expect the lignite at that depth. The upper marl would be in the position of the Pendleton beds and the lower one some-

what about the Shackelford bluff horizon. Beds of lignite outcrop in the creek branches southeast of Stone Coal bluff and tend to confirm the dip observations.

This occurrence is interesting for it seems to indicate that east of the Sabine river, the Lower Claiborne beds overlap the Lignitic beds shown in Sabinetown bluff. This is further confirmed by the fact that at Many the Sabinetown beds seem to be lacking.

Chireno well.—In Texas the well recently drilled by the Mammoth Oil, Mineral and Land Co. near Chireno furnishes a section which gives some idea of the development of this stage west of the Sabine river. This well is about three miles south of the Lower Claiborne-Lignitic line of parting.

Well Section, Chireno, Nacogdoches Co., Texas

			Feet.
1.	0-110	Red fossiliferous marl containing *Ostrea falciformis*, *Anomia ephippioides* in upper portions. Below changes to blue grey	110
2.	110-112	"Oil sand." This outcrops to the north at the base of the Lower Claiborne	2
3.	112-382	Blue to grey fossiliferous marl	270
4.	382-462	White quicksand. Strong flow of artesian water	80
5.	462-468	Dark grey lignitic clay	8
6.	468-477	Lignite	9
7.	477-515	White quicksand	38
8.	515-522	Lignite	7
9.	522-562	Grey-blue sand, with very small shell fragments. Layer of pyrites 3 inches thick at base	40
10.	562-632	Blue micaceous sand. Fragments of shells reported but sample shows only glittering particles of mica	70
11.	632-636	Hard fossiliferous greensand	4
12.	636-676	Dark green sand	40
13.	676-736	Soft, dark grey lignitic clay	60
14.	736-826	Chocolate to yellow laminated clay	90
15.	826-836	Indurated grey sand	10
16.	836-840	White clay	4

UPPER LIGNITIC EOCENE, SABINETOWN BLUFF, TEXAS

17.	840-865	Grey sand with a little oil................	25
18.	865-873	Hard sand..............................	8
19.	873-877	Hard rock not passed through...........	

LOWER CLAIBORNE

Preliminary remarks.—The Lower Claiborne extends from Bayou Negreet to Columbus and probably slightly beyond. It shows in its development the Texan phase of the Lower Claiborne fauna. The dips are pronouncedly west of south about the mouth of Bayou Negreet and agree almost exactly with the Lignitic dips obtained above. Near Goodwin's shoals the dip changes abruptly to east of south. This change in dip occurring as it does in the middle of a formation is possibly due to orogenic movements which are also responsible for the shoals on this river.

The paleontology of these beds will be discussed by Prof. Harris in a forthcoming bulletin on the Lower Claiborne stage.

Low creek beds.—The peculiar beds described from Low's creek, near Sabinetown, in 1899 and referred provisionally to the Lignitic show a much better development on the Sabine near the mouth of Low's creek at stations 19 and 20. The beds here furnish a much more complete fauna, especially at the Negreet outcrop, and Harris is inclined to regard the material as having a decided Lower Claiborne aspect. Directly above it is a well marked Lower Claiborne fauna and the position of these beds at or near the line of parting between the Lower Claiborne and Lignitic is fully proven.

Section at 19.

		Feet	In.
1.	Gray sand................................	5	
2.	Grey and yellow unstratified clay containing ferruginous gravel. Beds 1 and 2 lie unconformably on those below......................	25	0
3.	Dark green limestone filled with large grains of greensand. Characterized by great numbers of *Pecten cornuus* and crustacean remains........	5	0
4.	Fossiliferous öolitic greensand with occasional spots of green clay, weathering red................	7	0

5. Ledge of green limestone containing small rounded greensand grains. Weathers red 0 4
6. Fossiliferous green clay with much greensand... 10 0

The fossils are all small and rather poorly preserved. Dip S. 50° W. 1:60.

Just above the mouth of Bayou Negreet a low ledge is exposed under a bed of grey and yellow sands and clays. Here twenty-five feet of the same material seen in foregoing section is exposed.

Section at Mouth of Bayou Negreet

		Feet.
1.	Light grey and yellow sandy clay with gravel at base. Extends over whole outcrop	20
2.	Dark greenish brown clay with greensand grains. About four feet from base is a harder portion of the bed forming a little terrace	13
3.	Very fossiliferous indurated green marl weathering brown. Contains among other shells *Ostrea falciformis*	4
4.	Hard limestone with many large *Venericardia planicosta*	2
5.	Covered. (Mouth of Bayou Negreet)	20
6.	Laminated, chocolate colored clay	2
7.	Hard, grey limestone with imperfect shells and bowlders of the underlying material. Contains *Ostrea falciformis*. Similar in every respect to Lower Claiborne outcrop described in 1899 from Low's creek. Shows large masses of coral	3
8.	Same material as section at 19, described above, but here containing a greater percentage of clay. This outcrop has more of the appearance of normal green sand marl. It weathers into six distinct shelves because of difference of hardness in different portions of the bed	25

Layer 7 of this section crosses the river at right angles giving rise to a very marked shoals. The river flows against the inclined edges of the strata. Dip from a long exposure, S. 20° W. 1:25.

In the middle of the river opposite the mouth of Bayou Negreet there is a rocky island, 7 feet high, made of ferruginous conglo-

merate. The conglomerate shows casts of *Venericardia planicosta*, *Volutilithes* and *Unio*.

Outcrops from Bayou Negreet to Columbus.—At 20, 3 miles above Columbus, is a bluff greatly complicated with landslips. Ten feet of irregularly stratified yellow sand with irregular clay partings is here overlaid with a layer of laminated dark brown clay having a maximum thickness of 20 feet. Capping the bluff is the usual fine grey and yellow sand, here 15 feet thick.

Along the east and west reach above Columbus, on the Texas bank, there are a number of outcrops of very fossiliferous Lower Claiborne. At 21 a long shelf, ten feet high, shows the following section:

Section at 21

		Feet
1.	Grey and yellow sands and clays	15
2.	Very dark grey fossiliferous laminated clay with lines of concretions. Contains a characteristic Lower Claiborne fauna. Among other forms *Belosepia ungula*, *Turretella nasuta* var. *houstonia*, *Clavilithes penrosei*, *Cornulina armigera* (small)	9
3.	Covered	3
4.	Very fossiliferous greensand. Many fossils silicified	2
5.	Finely laminated bluish grey sandy clay with traces of vegetable matter	6

Dip here seems to be due south.

A quarter of a mile below this outcrop, at 22, the following section is shown:

Section at 22

		Feet
1.	Unexposed to top of bank	14
2.	Pebble conglomerate	2
3.	Laminated, dark brown clay and yellow sand, containing fossils irregularly through the whole mass. *Anomia ephippoides* is very common	23

Dip a little west of south.

The best collecting in the Lower Claiborne occurs at 23, two miles by river, above Columbus.

Section at 23

		Feet	In.
1.	Grey and yellow sandy clay with small ferruginous gravel. Clayey portions weather into little pinnacles	20	0
2.	Bluish grey laminated clay with sand partings and occasional patches of sand. Marked ledge of concretions in upper part of bed	11	0
3.	Dark green shell limestone weathering red. Contains many specimens of *Arca rhomboidella*	0	6
4.	Same as 2 but much more fossiliferous	4	0

Dip southwest.

The lower layer is filled with a great variety of beautifully preserved Lower Claiborne forms.

Columbus.—The bluff at Columbus is much complicated with landslips and it is impossible to get a very satisfactory section. The following is from the best exposures:

Section at Columbus

		Feet
1.	Fine grey sand, tinged with yellow	8
2.	Pebble conglomerate	2
3.	Drab clay with small concretions	4
4.	Ledge of fossiliferous dark grey limestone with *Plicatula filamentosa*, *Pectunculus idoneus*, *Arca rhomboidella*	1
5.	Light green, laminated, fossiliferous clay	20
6.	Light green, laminated, fossiliferous clay with large numbers of *Ostrea johnsoni*, var. and *O. falciformis*	4
7.	Ledge of calcareous concretions	1
8.	Same as 5	3

Bluff so complicated with landslips that dip observations are unsatisfactory; dip seem to be south, a little east.

Small outcrop of fossiliferous Lower Claiborne at 24.

At 25 is a high bank used for a log-slide. Here a ledge of greensand 2 feet thick, appears at water level and extends half across the river. It is covered with the usual grey and yellow sands and clays. Dip S. E. 1:50.

COCKSFIELD FERRY BEDS

Preliminary remarks.—The Cocksfield ferry beds are well developed in the vicinity of the Sabine river and show the typi-

JACKSON EOCENE NEAR ROBINSON'S FERRY

cal, unfossiliferous, lignitic clays, with large calcareous concretions, which characterize them. Beds of this series are the lithological counterparts of the beds of the lower Lignitic and occupy a position between the fossiliferous Lower Claiborne and Jackson beds.

Outcrops.—The first bluff below Columbus shows the following section:

Section at 26

		Feet
1.	Fine white sand	20
2.	Dark grey to blue sandy clay with fine sand partings and occasional beds of yellow sand, in many places a foot thick. Contains many poor plant impressions and a few calcareous concretions	28

Dip S. 20° E. 1:20.

A quarter of a mile south of the above outcrop, at Lawhorn's bluff, 26 feet of laminated sandy clay, containing many large calcareous concretions, is exposed. A bed of impure lignite, a foot thick, occurs about three feet above low water level. Dip S. E. 1:70.

Three shelves of dark colored clay appear near water level between Lawhorn's bluff and Robinson's ferry at 27, 28 and 29. At 28 the bed is 6 feet thick and has the usual covering of light colored sands.

JACKSON

Preliminary remarks.—It was a delightful surprise to find a most typical Jackson fauna just below Robinson's ferry. The considerable thickness of the Jackson beds here indicated that careful search would reveal Jackson in Texas, and recent work has shown Jackson fossils near Caddel P. O. in clayey marls and in the white sandstones directly above them. The area there occupied by the Jackson outcrop is rather considerable. Large bones (perhaps *Zeuglodon*) are reported in the Jackson area east of the Sabine on Caney creek.

Outcrops.—About three-fourths of a mile below Robinson's ferry, at 30, there is an outcrop of 5 feet of blue fossiliferous

clay on the Texas side of the river (see Plate XXX). It shows at this stage of the river two large concretions of hard white fossiliferous limestone. The outcrop yielded a rather extensive Jackson fauna including *Umbrella planulata* and many large *Capulus americanus*.

At 31, a shelf of the same fossiliferous clay shows on the Louisiana side. The fossils here are not so well preserved. Dip S. 20° E.

Between this outcrop and the outcrop of the Grand Gulf near Anthony's ferry, ledges of Tertiary clays show at 32, 33, 34 and 35. At 34 a few fossils are exposed.

Section at 33

		Feet
1.	Dark grey and brown mottled sandy clay ("buckshot clay")	18
2.	White and yellow pebbly sand	5
3.	Blue clay weathering brown	10
4.	Irregularly bedded, laminated, slate colored clay and yellow sand	3
5.	Laminated chocolate-colored clay with occasional thin seams of yellow sand and small calcareous concretions	8

The layers 3, 4 and 5 show a southward dip of 1:25. Near the northern end of the exposure is a small fault with a throw of about 6 feet.

OLIGOCENE

GRAND GULF

Preliminary remarks.—For stratigraphical purposes, and until fossils are found which will render the beds susceptible of division, it would seem well to include under this term the lower portion of Hilgard's Grand Gulf or that portion which contains sandstone beds. These form a stratigraphic unit readily distinguished from the thick beds of green calcareous clays which overlie them and which are now known to be Chattahoochee Oligocene.

No animal remains, save a few Unios, have yet been found in the Grand Gulf sandstones. Kennedy reports an Eocene fauna from the *base* of the series and on these fossils correlates the

GRAND GULF OLIGOCENE NEAR ANTHONY'S FERRY

beds for several hundred feet *above* the outcrop with the Lower Claiborne. These fossils, which prove to be Jackson, can hardly be said to prove the age of the beds *above* them and considering the overlap of the Grand Gulf beds on the Jackson, as shown in Louisiana, it is not surprising to find Jackson fossils in the sandstones a few feet above the Jackson clays. Considering the evidence at hand there seems to be no reason for regarding the Grand Gulf sandstones of Texas as different from the Grand Gulf sandstones of Louisiana and Mississippi. The finding of a Chattahoochee fauna in the green clays adds to the characters in common between these beds and the same beds across the Mississippi.

The Grand Gulf sandstones extend along the Sabine from Anthony's ferry to near Burr's ferry. The southeastward dip observed in the Cocksfield ferry beds and the Jackson continues to a point below Hattan's ferry with a tendency to show an increased dip. Near Burr's ferry the dip becomes much less being 1:300.

Outcrops from 36 to Snell's landing.—A shelf of soft, fine, grey sandstone with a slight amount of calcareous matter is exposed on the Louisiana side at 36. Plate XXXI shows this exposure and also shows the way in which these shelves of older material appear under the ordinary bottom bank.

At 37, a much larger shelf occurs near low water level. It extends well across the river producing a decided acceleration of the current. The section is:

Section at 37

		Feet
1.	Yellow and brown silty sand to top of bank	8
2.	White to grey sand with faint traces of stratification. Contains pebbles at base..........................	10
3.	Hard, fine-grained quartzitic sandstone...............	2
4.	Greyish-blue, jointed sandy clay becoming lighter and more sandy above	15
5.	Soft, white, fine-grained sandstone..................	8
6.	Coarse-grained quartzitic sandstone..................	3
7.	Grey to drab, jointed sandy clay....................	3

Dip S. E. 1:50.

At Anthony's ferry a small flat-topped bluff on the Texas side shows no rock. On the Louisiana side, a little below, 4 feet of fine-grained Grand Gulf sandstone shows near water level.

Just above Snell's landing, a flat-topped bluff 35 feet high shows at its base 8 feet of blue sandy clay.

Bluffs near Snell's landing.—At Snell's landing high bluffs appear on the Texas side and extend for two miles down the river.

Section at Snell's Landing

		Feet
1.	Fine white sand with pebbles at base	25
2.	Covered	12
3.	Coarse, indurated white sand, capped with a layer of sandstone about a foot thick	8

Water level.

Dip. S. E. 1:25.

A mile below this exposure there is a good exposure at 38.

Section at 38

		Feet
1.	Unexposed to top of bluff	40
2.	Yellow sand, containing bowlders of buff colored, laminated, leaf-bearing clay	35
3.	Coarse, white, cross-bedded, rather quartzitic sandstone, mottled with yellow	6
4.	Greenish-yellow sandy clay	20
5.	Unexposed	10

Water level.

Bed 2 shows a phenomena almost identical with that shown in the K. C. P. & G. R. R. cut near Shreveport, where the beds are presumably of lower Eocene age. Five hundred yards below this section, at 39, this bed is much more fully developed. Here the bed is covered with a regularly bedded, laminated, brown to slate-colored clay, three feet thick, with abundant plant impressions.

This line of bluffs extends along the river half way to the mouth of Bayou Toro. The quartzitic sandstone increases in thickness, reaching a maximum of 10 feet near the lower end. This sandstone layer indicates that the line of bluffs are about on the line of strike and hence the dip is S. E.

Hattan's ferry to Burr's ferry.—Near Hattan's ferry on the Louisiana side the following section is shown :

Section Hattan's Ferry
(East Bank)

		Feet
1.	Drab, iron-stained clay crumbling into small irregular pieces ("Buckshot clay")	17
2.	Fine white sand with many small pebbles	3
3.	Blue clay weathering yellow (Grand Gulf)	5

A flat-topped bluff on the west side of the river at 40, shows a ledge of green jointed clay about five feet thick. The great southward dip, 1:25, exposes about 20 feet of this bed.

Sandstone ledges cause several shoals in the river below this outcrop but afford no good exposures. At 41 a ledge of fine grained, porous sandstone shows a slight southward dip 1:300.

At 42, a range of high hills, rising over a hundred feet above the river, approach the river on the Texas side. One hill-point just reaches the river and exposes a ledge of sandstone near the water line. Forty feet above water level a ledge of sandstone 25 feet thick outcrop in the hillside; in many places forming a protruding ledge and giving rise to a number of small waterfalls where little streams from the hills flow over it.

About a mile above Burr's ferry, at 43, there is a small outcrop of soft white sandstone. This is covered with the usual pebble-bearing sands and pinnacled clays.

FRIO CLAYS

Preliminary remarks.—Overlying the sandstones of the Grand Gulf, in western Louisiana and eastern Texas, are thick beds of green calcareous clay, which produce a stiff, heavy soil, often black and prairie like. These black and mulatto lands extend along the K. C. P. & G. R. R. from Pickering to Neame and include many prairies, as Anacoco prairie and the prairies about Hardshell. Along the Sabine river these clays extend from Burr's ferry to Droddy's landing and westward, in Texas, they extend in a belt five to fifteen miles broad across Newton and Jasper counties to the Neches river, where they are very finely developed sections at Town bluff and the bluff ten miles below.

The Town bluff section is the most complete that has come under the notice of the writer.

Fossils collected near Burkville are regarded by Harris as representing a brackish water phase of the Chattahoochee Oligocene. It is impossible from our present observation to say how far from the base of the green clays these fossils occur (it is probably over a hundred feet) and how much, if any, of the upper portions of the Grand Gulf proper belong to this stage. On the map and in our consideration of the Sabine river section we have made the last hard sandstone layer in the Grand Gulf the dividing line. This is of course purely arbitrary.

These beds seem to be very nearly equivalent to Kennedy's Frio clays. His description however seems to partially indicate that he regards these clays as occupying a position beneath the upper sandstones. If this be the correct interpretation of his meaning we would suggest the name *Burkville beds* for this stage.

Outcrop near Burr's ferry.—A small outcrop of the greenish-yellow clays of this stage occurs at the water's edge a quarter of a mile from Burr's ferry.

Bluff at mouth of Boggy branch.—Bluff just below the mouth of Boggy branch shows the following section :

Section Boggy Branch Bluff.

		Feet
1.	Stiff black soil	1
2.	Fine white sand	37
3.	Light yellow, sticky clay, containing large irregular white calcareous concretions. Weathers into a stiff black clay	26
4.	Covered to water level	17

The blackland soil which caps this bluff is an erosion fragment of a much thicker bed which shows in the hills west of this exposure. This is a continuation of the blackland belt in which fossils occur at Burkville.

New Columbia.—Shelf of clay exposed just below the ferry shows the following section :

Section New Columbia, Texas

		Feet
1.	Yellow sandy loam mottled with grey	7
2.	Fine white and yellow sand containing gravel in the basal portion	13
3.	Light brown, slick-looking clay, streaked with white. Contains small calcareous concretions	2
	Water level.	

The flat-topped bluff on which New Columbia is situated continues down the river half a mile. Near its lower end a ledge of green calcareous clay, two feet thick, is exposed near water level.

Outcrops below New Columbia.—The first exposure of Frio clays below New Columbia is at the log-slide at Knight's landing.

Section Knight's Landing.

		Feet
1.	Brown sandy silt, stained with red and yellow	7
2.	Stratified white sand with gravel at base	17
3.	Green sandy clay	10

Two feet of green sandy clay is exposed at base of low pineclad bluff on the Louisiana side between Droddy's landing and Bearden's ferry.

PLIOCENE AND RECENT

LAFAYETTE AND PORT HUDSON

Preliminary remarks.—Along the river, as on the hill lands on either side, the Miocene and much of the Pliocene appear to have no surface outcrops, the mantel of Lafayette gravel extending without an erosion break to the Oligocene beds. All the bluffs from the last exposure of the Frio clays to the gulf show nothing but the gravels, sands and loams noticed as forming the upper parts of the preceding sections. The relation of the beds on the tops of the bluffs to those in the bottoms and these in turn to the other bottom deposits is a most perplexing problem.

In the upper part of the river the sands and gravels besides capping the bluffs appear to underlie the whole bottoms. The section commonly shows gravel at the base, sand in the center and grey or brown pinnacled clays at the top but the section is

not invariable. These beds of sands and gravel appear in banks along the river no higher than the ordinary bottom banks and pass horizontally into beds of grey and brown clay which one would naturally regard as recent river deposits. The brown clay sometimes shows cypress stumps, 15 feet below the present bank level (at 44 and other places along the river). On the whole, in the upper part of the river, the amount of material which may be regarded as recent river deposit appears to be very small and to be confined to the sandbars and the very thin veneer of alluvium deposited over the bottom plain in times of flood. The plain seem to be one formed by the filling of a valley with sediment and not by base leveling. The river is now engaged in cutting out the material which was deposited in the valley and should in time produce the terraces of which the flat-topped bluffs are a suggestion.

In the river below the mouth of Anacoco bayou the sands and gravels appear only in the low, flat-topped bluffs which touch the river at intervals. The size of the gravel in these bluffs and the percentage of sand grows less as we approach the gulf and red and yellow sandy loams replace them.

With regard to the relative age of the beds which cap the high bluffs, the beds which occupy the river bottoms and the ones which form the bluffs of the lower river we do not feel competent to judge. But there can be little doubt that the bottom deposits and the material which forms the bluffs of the lower river represent the riverward development of the deposits which form the upper portions of the coastal plain in southern Louisiana and Texas. The gravels and sands and clays of the high bluffs, which in lithological characters are identical with those of lower levels, may have been laid down at the same time or the lower deposits may represent a redeposition of the upper deposits. These deposits, as a whole, are identical with those which have been regarded as Lafayette and Port Hudson in other parts of the country.

Outcrops from Logansport to Stark's ferry.—Much of the material belonging to this series has been described in the upper parts of the sections given above but a few localities remain to be noticed.

At 3 there is a clean bank that shows a section which may be regarded as typical of this portion of the river. It shows 18 feet of light colored sands and clays. One portion of the bed, near the center of the bank, contains enough lime to partially cement the sands and clays.

The top of Hart's bluff, which is 60 feet above low water level shows 11 feet of light grey and yellow sands which lie unconformably on the Lignitic Eocene clays. This bed contains numbers of small rounded ferruginous concretions and is much stained with oxides of iron. On the north side of the bluff these beds pass into the bank deposits.

About a mile below Myrick's ferry (Plate XXXII) is a very instructive section. Here white and yellow sands grade laterally into grey and yellow pinnacled clays similar to the beds which cap the bluff at Myrick's ferry and these in turn grade into brown unstratified buckshot clays of the river bank.

Seventeen feet of stratified white and grey sands with pebbles in the basal layers and overlaid by 8 feet of yellow sandy loam, outcrop at 35. This bank is in no sense a bluff, being merely the ordinary river bank.

The river banks between Anacoco and Stark's ferry are from 6 to 10 feet high, and are composed of greyish brown loamy clay.

Stark's ferry to Sabine lake.—At Stark's ferry the type of "bluffs" common on the lower river is well shown. The top of the bluff is very near the level of the surrounding country for many miles, and the riverward exposure shows the following section:

Section Stark's Ferry

		Feet
1.	Mottled, yellow, brick red and grey sandy clay showing irregular lines of stratification and containing occasional pebbles	12
2.	Coarse cross-bedded, white sand with quartz and chert pebbles to water level	7

Gravel shows on both sides of the river within a quarter of a mile.

Two bluffs occur between Stark's and Belgrade at points indi-

cated on Plate XXXIV. They are respectively 27 and 20 feet high and are covered with old field pine, and composed of Orange sand.

Section Upper Belgrade

		Feet
1.	Fine yellow sand growing darker and finer till in its upper portions it is a brick red loam	10
2.	Coarse, cross-bedded white sand with numerous pebbles	18

At Whitman's ferry the only addition to the section above is the presence at the very base of the bluff of two feet of light grey clay. Height of bluff 21 feet.

Small bluff on the Texas side about two-thirds way from Salem to Nix's ferry shows no new features.

Nix's ferry bluff, 15 feet high, exposes light grey sandy clay stained with iron and containing numerous ferruginous gravel about the size of shot. The sandy clay weathers into sharp pinnacles, the iron gravel giving it a granular appearance.

Sudduth's bluff is 12 feet high and is composed of fine, stratified, white, yellow and red sand. The upper five feet, save for a leached layer at the surface, is brick red. No pebbles were seen.

Five low bluffs were noticed between Sudduth's and the low bluff at Deweyville. At two of them small erratic pebbles were noted.

The bluffs at Morgan's, Pruit's, Niblett's and Orange are extremely similar and show no additional features.

GENERAL CONSIDERATIONS

Relation of Sabine River Section to Other Sections

The section along this river agrees, in general, rather closely with the Alabama and Mississippi sections. It differs from them mainly in (1) the great development of the thick beds of unfossiliferous lignitic clay near the base of the Lignite; (2) the development of the unfossiliferous clays which lie between the fossiliferous Lower Claiborne and Jackson beds; (3) in the absence of the Claiborne sand; (4) in the absence of the Vicksburg limestone. The Claiborne sand seems to be a very local development about Claiborne landing, Alabama, and its absence is not surprising. Irregular continental warping has caused the

Grand Gulf shore line to overlap the Vicksburg from Little river in Louisiana, westward and hence the Vicksburg stage is not exposed.

The differences, on the whole, are not nearly so great as the early work of the Texas survey seemed to indicate and enough information is now at hand to enable us to correlate the East Texas horizons more exactly. The following table gives a graphic representation of the equivalence of Kennedy's Texas section published in the proceedings of the Philadelphia Academy: *

* The Eocene Tertiary of Texas east of the Brazos by William Kennedy, Proc. Phila., Acad. Nat. Sci., vol. 47, p. 92, 1895.

CORRELATION TABLE

<table>
<tr><th colspan="3">Kennedy's Texas Section</th><th colspan="2">Interpretation</th></tr>
<tr><td rowspan="6">Eocene</td><td rowspan="5">Lower Claiborne</td><td>Frio clays</td><td>Frio clays
(Chattahoochee)</td><td rowspan="2">Oligocene</td></tr>
<tr><td>Fayette sands</td><td>Grand Gulf</td></tr>
<tr><td rowspan="2">Yégua clays</td><td>Jackson</td><td rowspan="4">Eocene</td></tr>
<tr><td>Cocksfield</td></tr>
<tr><td>Marine Beds</td><td>Lower Claiborne</td></tr>
<tr><td>Lignitic</td><td>Queen City Beds
Lignitic</td><td>Woods Bluff
Nanafalia
Basal Lignitic</td></tr>
</table>

MAP

OF THE

SABINE RIVER

FROM THE

GULF OF MEXICO TO LATITUDE 32° NORTH

In five sheets

1902

SCALE: 1:375000

5 0 5 10 15

Miles

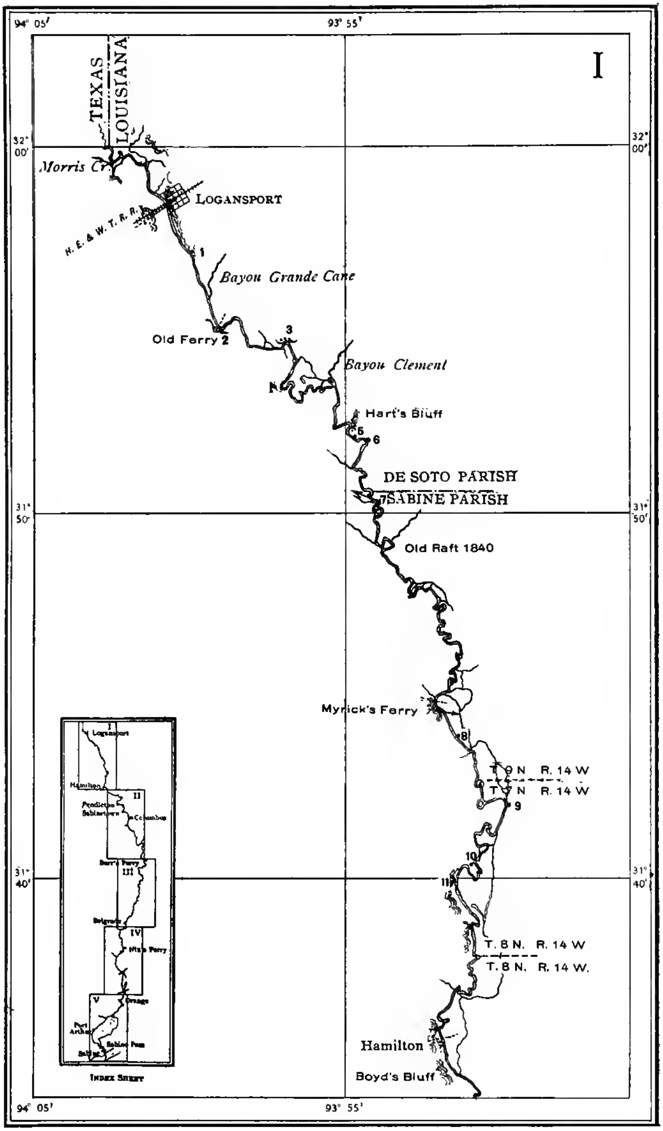
AUTHORITIES

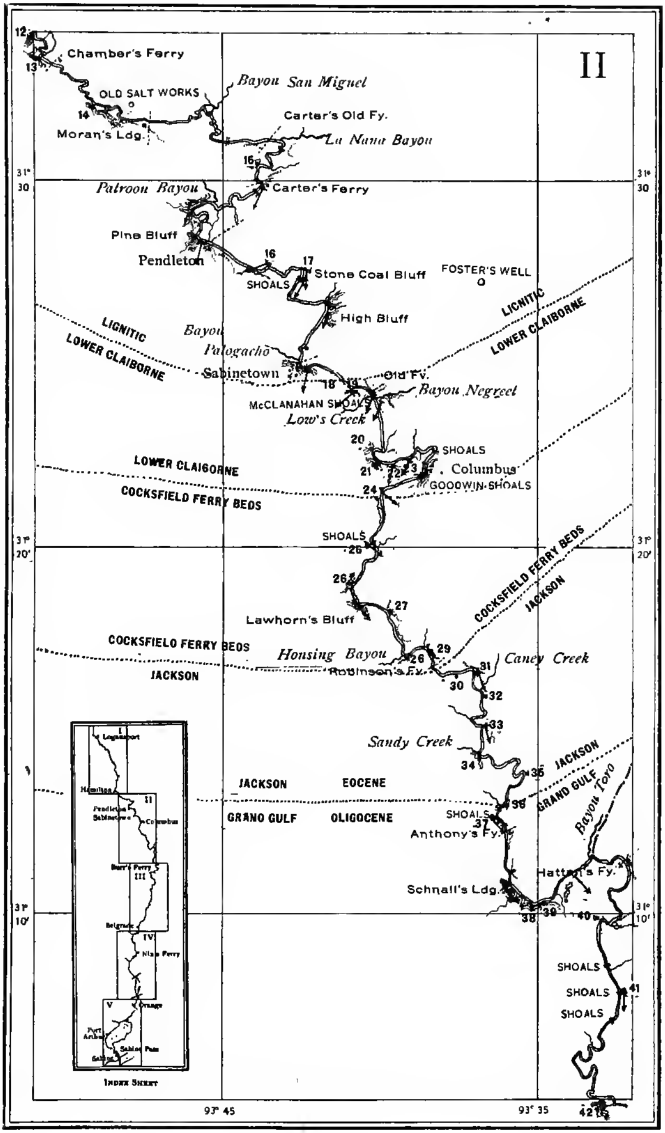
Geographic Positions.—United States-Texas Boundary Survey 1840–1841; Maj. J. G. Graham, U. S. Topog. Eng.; Lieut. Thos. J. Lee, U. S. Topog. Eng.; U. S. Coast and Geodetic Survey; Chart No. 203; Texas-Ark. boundary line at Texarkana, Edwin Smith, E. D. Preston.

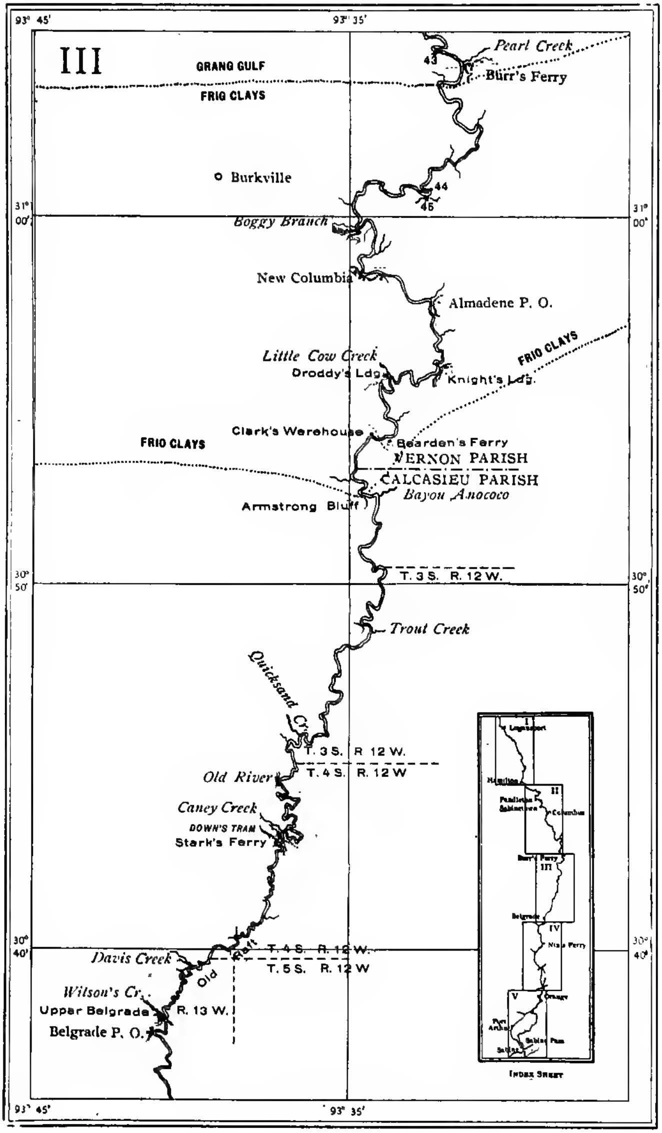
Hydrography.—Sabine Lake, Lieut. J. H. Eaton, U. S. A., 1837; Sabine Lake to Hamilton, J. H. Polhemus, Asst. U. S. E., 1878; Hamilton to Lat. 32° north, F. P. Leavenworth, Asst. U. S. E., 1873; Coast and Sabine Pass, Chart No. 203 U. S. Coast Survey; Sabine Pass and Jetties, J. L. Brownlee, Asst. U. S. E., 1899.

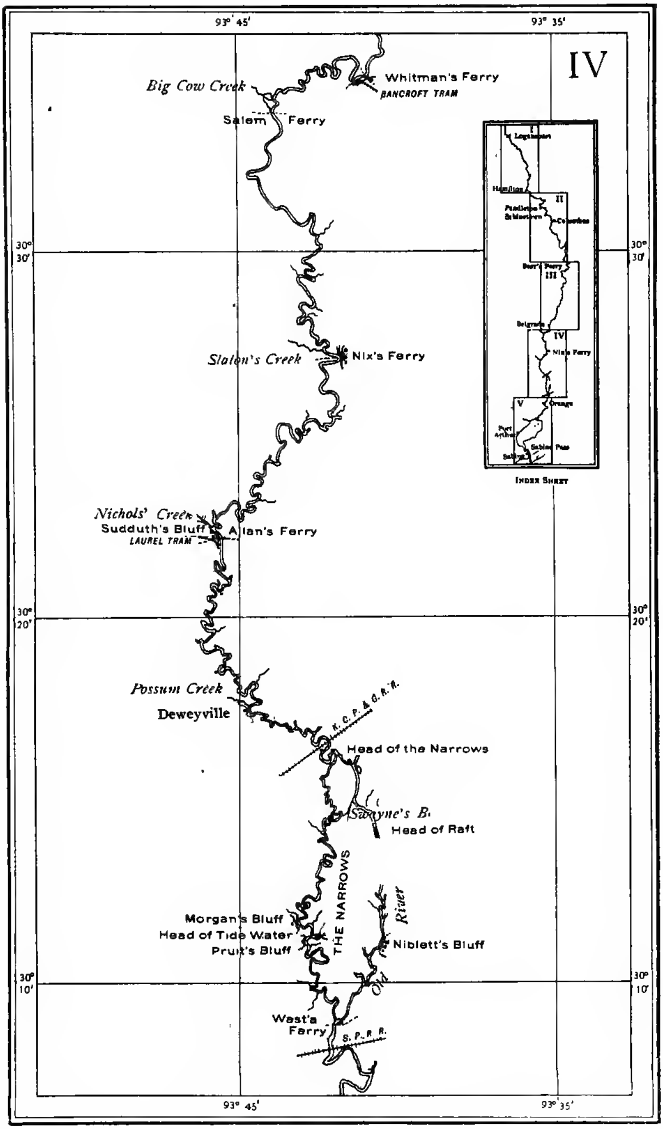
Topography and Geology.—A. C. Veatch 1900.

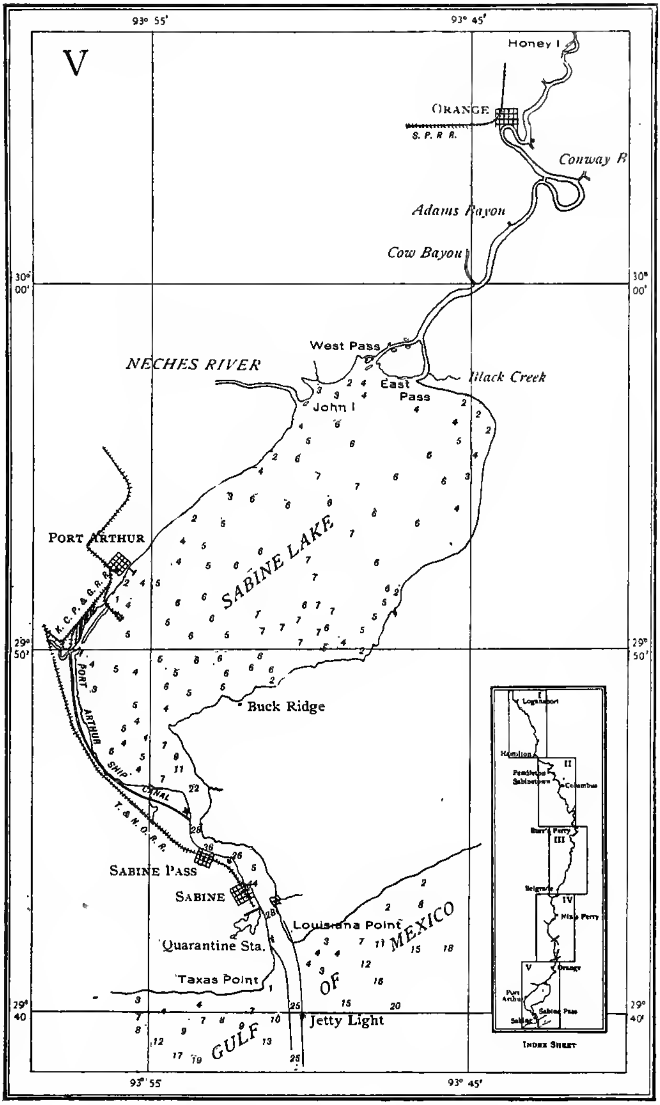
Drawing.—A. C. Veatch 1901.


94° 05'
93° 55'
I
TEXAS
LOUISIANA
32° 00'
Morris Cr.
LOGANSPORT
H. E. & W. T. R. R.
1
Bayou Grande Cane
Old Ferry 2
3
Bayou Clement
4
Hart's Bluff
5
6
DE SOTO PARISH
7 SABINE PARISH
31° 50'
Old Raft 1840
Myrick's Ferry
8
T. 9 N R. 14 W
T. 9 N R. 14 W
9
10
31° 40'
11
T. 8 N. R. 14 W
T. 8 N. R. 14 W.
Hamilton
Boyd's Bluff
INDEX SHEET


II
Chamber's Ferry
Bayou San Miguel
OLD SALT WORKS
Moran's Ldg.
Carter's Old Fy.
La Nana Bayou
Patroon Bayou
Carter's Ferry
Pine Bluff
Pendleton
Stone Coal Bluff
SHOALS
FOSTER'S WELL
High Bluff
LIGNITIC
LOWER CLAIBORNE
Bayou
Palogacho
Sabinetown
Old Fy.
Bayou Negreet
McCLANAHAN SHOALS
Low's Creek
SHOALS
Columbus
GOODWIN SHOALS
LOWER CLAIBORNE
COCKSFIELD FERRY BEDS
SHOALS
Lawhorn's Bluff
COCKSFIELD FERRY BEDS
JACKSON
Housing Bayou
Robinson's Fy.
Caney Creek
Sandy Creek
JACKSON
EOCENE
GRAND GULF
OLIGOCENE
Bayou Toro
SHOALS
Anthony's Fy.
Hatten's Fy.
Schnall's Ldg.
SHOALS
SHOALS
SHOALS
31° 30
31° 20'
31° 10'
93° 45
93° 35
INDEX SHEET
Logansport
Hamilton
Pendleton
Sabinetown
Columbus
Burr's Ferry
Belgrade
Nibletts Ferry
Orange
Port Arthur
Sabine Pass
Sabine


93° 45'
93° 35'
III
GRANG GULF
FRIO CLAYS
Pearl Creek
Burr's Ferry
43
Burkville
44
45
31° 00'
Boggy Branch
New Columbia
Almadene P. O.
Little Cow Creek
Droddy's Ldg.
Knight's Ldg.
FRIO CLAYS
Clark's Werehouse
Bearden's Ferry
FRIO CLAYS
VERNON PARISH
CALCASIEU PARISH
Bayou Anococo
Armstrong Bluff
T. 3 S. R. 12 W.
30° 50'
Trout Creek
Quicksand Cr.
T. 3 S. R. 12 W.
T. 4 S. R. 12 W
Old River
Caney Creek
DOWN'S TRAM
Stark's Ferry
30° 40'
Davis Creek
T. 4 S. R. 12 W.
T. 5 S. R. 12 W
Old Raft
Wilson's Cr.
Upper Belgrade
R. 13 W.
Belgrade P. O.
INDEX SHEET
I
II
III
IV
V


93° 45'
93° 35'
IV
Big Cow Creek
Whitman's Ferry
BANCROFT TRAM
Salem Ferry
30° 30'
Slaton's Creek
Nix's Ferry
Nichols' Creek
Sudduth's Bluff
Allan's Ferry
LAUREL TRAM
30° 20'
Possum Creek
Deweyville
K. C. P. & G. R. R.
Head of the Narrows
Swayne's B.
Head of Raft
THE NARROWS
River
Morgan's Bluff
Head of Tide Water
Pruit's Bluff
Niblett's Bluff
Old
30° 10'
West's Ferry
S. P. R. R.
INDEX SHEET
Orange
Sabine Pass
Nix's Ferry


V
93° 55'
93° 45'
Honey I
ORANGE
S. P. R. R.
Conway B
Adams Bayou
Cow Bayou
30° 00'
West Pass
NECHES RIVER
Black Creek
East Pass
John I
SABINE LAKE
PORT ARTHUR
K. C. P. & G. R. R.
29° 50'
PORT ARTHUR SHIP CANAL
T. & N. O. R. R.
Buck Ridge
SABINE PASS
SABINE
Louisiana Point
Quarantine Sta.
Taxas Point
GULF OF MEXICO
Jetty Light
29° 40'
Logansport
Hamilton
Columbus
Orange
Sabine Pass
INDEX SHEET

EXPLANATION OF PLATE XXXVII.

SABINE RIVER SECTION

	Outcrop 42	
1.	Sandstone	25
	Outcrop 41	
2.	Fine grained sandstone	4
	Outcrop 40	
3.	Green joint clay	5
	Outcrop 38 and 39	
4.	Slate colored clay	3
5.	Yellow sand, containing large clay bowlders	35
6.	Coarse, crossbedded, rather quartzitic sandstone	6
7.	Greenish-yellow sandy clay	20
	Snell's bluff	
8.	Coarse, indurated white sand	8
	La. bank, above Snell's bluff	
9.	Blue sandy clay	8
	Near Anlhony's ferry	
10.	Fine-grained sandstone	4
	Outcrop 37	
11.	Hard, fine-grained quartzitic sandstone	2
12.	Greyish, blue, jointed sandy clay	15
13.	White, soft, fine-grained sandstone	8
14.	Coarse, quartzitic sandstone	3
15.	Grey to drab, jointed sandy clay	3
	Outcrop 36	
16.	Soft, white sandstone	5
	Outcrop 35	
17.	Blue sandy clay	3
	Outcrop 34	
18.	Fossiliferous blue clay	4
	Outcrop 33	
19.	Blue clay	10
20.	Laminated slate colored clay	3
21.	Laminated, chocolate colored clay with small calcareous concretions	8

	Outcrop 32	
22.	Laminated brown clay	6
	Outcrop 31	
23.	Fossiliferous Jackson marl	5
	Outcrop 30	
24.	Fossiliferous Jackson marl	5
	Outcrop 28 and 29	
25.	Slate colored clay	6
	Outcrop 27	
26.	Slate colored clay	6
	Lawhorn's bluff	
27.	Blue-green sandy clay with large calcareous concretions	22
28.	Lignite, impure	1
29.	Blue-green sandy clay	3
	Outcrop 26	
30.	Lignitic sandy clay with calcareous concretions	28
	Outcrop 25	
31.	Greensand marl	2
	Outcrop 24	
32.	Fossiliferous greensand	3
	Columbus	
33.	Light green fossiliferous clay capped with fossiliferous grey limestone 1 foot thick	21
34.	Ostrea bed	4
35.	Light green laminated, fossiliferous clay with small calcareous concretions in upper part	4
	Outcrops 21–22–23	
36.	Fossiliferous Lower Claiborne marl	30
	Outcrop 20	
37.	Laminated dark brown clay	20
38.	Irregularly stratified lignitic clay	10
	Bayou Negreet (Basal portions also at Outcrop 19)	
39.	Greenish-brown greensand clay	13
40.	Indurated greensand marl	4
41.	Limestone	2
42.	Covered	20
43.	Laminated, chocolate colored clay	2
44.	Hard, grey limestone	3
45.	Dark green oölitic green sand with many *Pecten cornuus* and crustacean remains	30
	Sabinetown	
46.	Lignitic clay	15
47.	Yellow sand	25
48.	Lignitic clay	40
49.	Clayey sand more or less fossiliferous	15

50.	Fossiliferous blue sand with concretions	6
51.	Brittle, shaly, drab clay	2
	Ledge above Sabinetown	
52.	Fossiliferous greensand	3
	High bluff	
53.	Laminated, drab to chocolate-colored clays	20
54.	Unexposed	25
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57.	Light brown, laminated clay	7.5
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59.	Blue sandy clay, upper part fossiliferous	11
60.	Yellow and grey sand	5
61.	Wavy, alternate layers of blue sand and clay	6
	Patroon Creek bluff (Stone Coal bluff, in part).	
62.	Lignite	0.8
63.	Covered	15
64.	Lignite	2
65.	Dark blue laminated clay	7
	Carter's ferry	
66.	Calcareous concretions	1
67.	Covered	30
68.	Lignite	0.5
69.	Dark blue, laminated, sandy clay, with calcareous concretions.	15
	Outcrop 15	
70.	Same as 69	4
	Outcrop 14	
71.	Dark clay	6
72.	Covered	10
73.	Light yellow sand with fine clay partings	10
74.	Blue fossiliferous clay	8
	Rocky bluff (Outcrop 12)	
75.	Sand with large leaf bearing concretions	56

Chireno Well

1.	Blue fossiliferous marl weathering red	110
2.	"Oil sand"	2
3.	Blue to grey fossiliferous marl	270
4.	White quicksand. Strong flow artesian water	80
5.	Dark grey lignitic clay	8
6.	Lignite	9
7.	White quicksand	38
8.	Lignite	7

9.	Grey-blue sand, somewhat fossiliferous	40
10.	Blue micaceous sand	70
11.	Hard fossiliferous greensand	4
12.	Dark greensand	40
13.	Soft, dark grey lignitic clay	60
14.	Chocolate to yellow laminated clay	90
15.	Indurated grey sand	10
16.	White clay	4
17.	Grey sand with a little oil	25
18.	Hard sand	8

FOSTER WELL

1.	Fossiliferous greensand marl	
2.	Lignite	5
3	Fossiliferous greensand marl	

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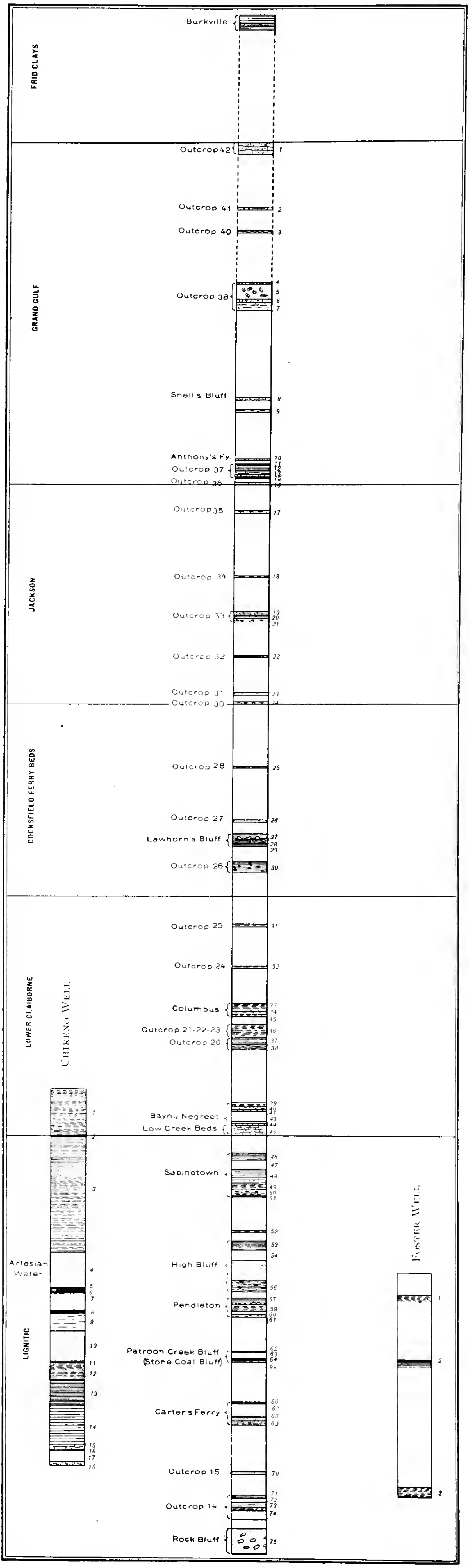

GEOLOGICAL SECTION ALONG SABINE RIVER.

Scale, 1 in. = 250 feet.

SPECIAL REPORT
No. IV

NOTES ON THE GEOLOGY ALONG THE OUACHITA

BY

A. C. VEATCH

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NOTES ON THE GEOLOGY ALONG THE OUACHITA RIVER

INTRODUCTION

During the extreme low water of the Ouachita river in the fall of 1899, when exceptional opportunities were afforded for examining the banks and bluffs, the writer made a canoe trip from Monroe to Harrisonburg. Nothing was known regarding the geology between Monroe and Columbia save the section of Lone Grave bluff given by Hopkins;* little was known of the river bluff sections at Columbia and it was hoped that something definite might be learned regarding the stratigraphic relationships of the known Jackson outcrops below this point.

In addition to information of stratigraphic interest, notes were collected regarding the origin of a series of peculiar lenticular islands which occur at intervals along the river between these points; and regarding the origin of Catahoula shoals and Sicily island, near Harrisonburg.

When possible the Indian mounds and camp-sites along the river were examined and notes regarding these will be found in the appendix.

PHYSIOGRAPHY

GENERAL DESCRIPTION

Between Monroe and Harrisonburg the Ouachita flows along the base of the bluffs which border, on the western side, the broad, recent plain of the Mississippi. It is true, the bottom lands along the Ouachita and Boeuf, are separated from those of the Mississippi, Tensas and Bayou Macon by the low, flat, fairly broad ridge known as the Bayou Macon hills but the material composing these hills, underlies the bottoms at no great depth and is to be regarded as belonging to comparatively recent valley deposits.

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* 1st. An. Rept. La. Geol. Surv., p. 85, 1870.

The river is from 800-1000 feet wide in ordinary stages of the water, with banks from 35-45 feet high. On the whole it seems to be slightly above its base level: (1) its slope curve, both high and low water, changes very rapidly between Monroe and Harrisonburg; (2) when compared with other streams of the same region its development of ox-bow bends, cut-offs and cut-off lakes is quite imperfect. Still it partakes much of the habitat of a meandering river in a flood plain as shown by the accompanying map, Plates XXXVIII and XXXIX, where the shading represents the ground occupied by the river but a short while ago. This indicates in a very graphic manner the tendency of a river to cut on the outside of its bends and deposit on the inside and shows in a slight degree the development of cut-off lakes.

The same map shows, in part, one of the anomalies of the river. After it had once entered the plain of the Mississippi, the river would hardly be expected to re-enter the hills, yet it does so just above Harrisonburg. Here it passes through a gap in the Grand Gulf sandstone, one of the most resistant formations in the state, and cuts off, between itself and the Mississippi plain, an island of rocky hill land.

ISLANDS

CLASSES OF ISLANDS IN FLOOD PLAIN RIVERS

A meandering river, at or near its base level, may show islands of the following types:

1. Cut-off islands.
2. Sand bar islands.
3. Islands due to inclosure by distributary channels.
4. Landslip islands.

These are all shown along the Ouachita, although the first three are not well developed and little need be said regarding them as the causes which govern their formation are so well understood that the words themselves, at least in the first two cases, have become almost self-explanatory.

Cut-off islands.—A river meandering in a flood plain forms great ox-bow bends which in time cut through at the neck forming islands between the new and old channels. No such islands

are shown on the map, but there are several which were islands at no very distant date as: at Blankston; west of St. Albans landing; north of Minden Hall* landing; east of Pritchard landing, and a most peculiarly shaped one near Hogan's landing.

Sand bar islands.—The second class may be formed: (1) by the production of areas of dead water, due to the deflection of the current by different curves of the banks, or to the disturbing influence of an inflowing stream; (2) by the checking of the current by obstructions—wrecks, snags and planters, giving rise to the "tow-heads" of the Mississippi. This form is not conspicuously developed along the Ouachita. Bars are more or less common but they are nearly all side bars and not island bars.

Islands due to inclosure by distributary channels.—A few bayous leave the river and, wandering through the bottoms connect with other bayous to the eastward forming islands of greater or less extent.

Landslip islands.—The last type of island is perhaps the most interesting to a geologist working on the Ouachita; first, because of their singularity, and second, because they are responsible for a number of outcrops of old Tertiary material which otherwise would not be exposed, and while such outcrops are clearly out of place they cannot be very greatly removed from the place of origin and they afford valuable data on the areal distribution of some of the formations.

These islands were noticed at intervals between Monroe and Columbia. They are long, narrow, reaching an extreme height of seven feet, and composed of old Tertiary clays often inclined at a high angle. In the island just across from Roselawn landing the dip is almost vertical, exposing one stratum, more resistant than the others, as a backbone down the center. The islands are generally near the western bank of the river but near Lapinière † landing a number of smaller islands occur near the eastern bank. It was on one of this series that a well preserved Lower Claiborne fauna was found (see below, page 160).

* So spelled on sheet No. 29 of the Ouachita River Survey, 1896. Locally it was given me as *Mindenhole*.

† Given *Lapile* and *La Pine* on Sheets 24 and 25 and *LaPiniere* on Index Sheet No. 2 of the Ouachita River Survey. La Pine is clearly a corruption of the old form *Lapinière* which refers to a rabbit warren and not to pines.

Below Columbia, near the bluffs, a number of these islands are developed and at Bunker hill their relation to the main bluff is well shown (Fig. 14).

Judging from the amount of displacement indicated by some of these landslip islands, and from the considerable distance of some of them from the present hill land, it is inferred that at the time of their formation the river systems of this region were at a lower level than the Ouachita is to-day.

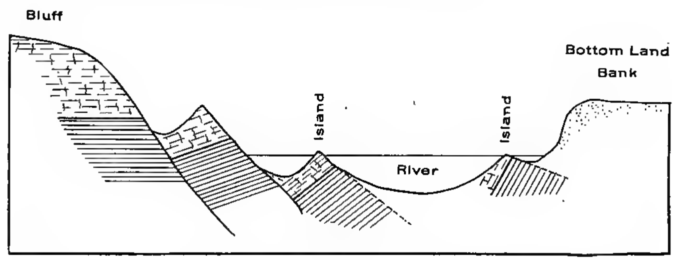

FIG. 14.—SECTION OF BUNKER HILL, SHOWING FORMATION OF LANDSLIP ISLANDS.

This creeping of the Tertiary clays is developed to a remarkable degree north of Many, La., where it produces quite an effect on the minor topography of the country. There, these landslip ridges are variously regarded as fortifications, old treasure holes and the like.

SICILY ISLAND

Of the Tertiary formations of this region the Grand Gulf has been most successful in resisting erosion ; the hard sandstones which form the base of this formation hold up the topography and are responsible for the escarpment which marks its northern limit from central Texas to eastern Mississippi. Even the Mississippi, or its ancestor not far removed, has experienced difficulty in cutting out the deposits of this age and we find that the valley is considerably contracted where this formation formerly crossed it (see Plate I). On the western side a great spur projects into the valley, of which the point, separated from the main hill mass by the Ouachita, is now known as "Sicily Island."

The Ouachita, where it passes through the hills, has a valley about a mile and a half wide at its narrowest place, just above Catahoula shoals. The length of this defile or gorge, if so broad and so short a cut may be called by such a term, is roughly five miles and for a mile and a half of this distance the river flows over rock. *

The topography of the surrounding country and the general aspect of the gorge indicate that the Ouachita here flows over a low lying divide between two antecedent valleys—valleys of tributary streams at a time when the land stood higher and the Ouachita, or its ancestors, flowed to the east of Sicily island. There are several reasons for believing that the Mississippi valley, not very long since, stood at a height at least 240 feet † above its present level. In such a case the gradients of all the tributary streams would be very greatly increased and a point, situated as this

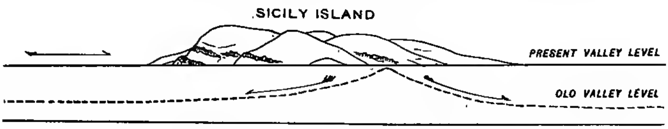

FIG. 15.—HYPOTHETICAL STREAM CURVES OF ANTECEDENT DRAINAGE, SICILY ISLAND, LA.

peninsula of Grand Gulf, would suffer greatly from erosion. It is believed that the completion of the formation of a low lying divide was affected during this period, and that, in the period of subsidence which followed, enough material was deposited in the valleys to entirely bury the old divide. No hindrance was now offered to the passage of the Ouachita through the combined old valleys and it has evidently, since, cut from side to side and slightly enlarged the channel thus afforded. Now that this part of the country is experiencing a slight uplift, as evidenced by the tendency of many of the streams occupying flat bottomed valleys in northern Louisiana to cut down into the underlying

* An. Rept. Chief of Eng. for 1890, Cross Sections of the Ouachita river at Catahoula shoals by J. M. Marshall, Asst. U. S. E., p. 1967.

† Depth of the Quaternary deposits at Lake Providence. Hilgard and Hopkins, Rept. on Borings between Memphis and Vicksburg, 48th Cong. 1st Sess., House Ex. Doc., vol. 19, 1884, p. 481.

beds and develop little rapids, the Ouachita has also cut out its channel slightly and found itself superimposed on the old divide. (See Fig. 15.)

While such a theory of the origin of Sicily island is, to a considerable degree, hypothetical it is believed that it will at least prove a suggestive working hypothesis. Indeed so far as the formation of the island is concerned, in the absence of fault structure this would seem to be the most normal explanation; supported as it is, not only by the data furnished by the Mississippi, but by the silted condition of all the stream valleys of northern Louisiana. (See topographic map of Many township, Plate IV, Geol. Surv. of La. Rept.for 1899.)

It may be that the old divide is more deeply buried and that the shoals have been formed in a way similar to those at Alexandria by the choking of the river by rafts, and the consequent enforced passage of the river over a low lying point of Grand Gulf sandstone.*

In this same connection it may be well to state that a line connecting the rapids at Alexandria with Catahoula shoals is very nearly parallel with the Winnfield-Coochie brake anticlinal, and the anticlinal now developing across the Sabine and Angelina rivers. While an origin by local crustal distortion is not impossible any evidence that such a thing is taking place is, at present, lacking.

STRATIGRAPHY

GENERAL STATEMENT

The succession of strata along the Ouachita, from Monroe to Harrisonburg may be summarized as follows:

Pliocene and Recent	Alluvium Port Hudson Lafayette ?
Oligocene	Grand Gulf Vicksburg
Eocene	Jackson Cocksfield Lower Claiborne

* See Geol. Surv. La. Rept. for 1899, pp. 160, 182.

EOCENE

LOWER CLAIBORNE

Preliminary remarks.—Lerch reported Lower Claiborne fossils from a well at Monroe at a depth of 185 feet.* These specimens had fortunately been preserved at Baton Rouge, but when examined the material was so strikingly like that found at Smithville, Texas, both in fauna and lithological characters, that Harris was inclined to doubt the correctness of the locality label.† The fact that no fossils had been found east of a line connecting Winnfield and Ruston, and that the territory seemed to be Cocksfield tended to confirm this doubt. The operations of the field season of the fall of 1899 solved this question by the finding of a number of fossiliferous Lower Claiborne outcrops along the Ouachita between Monroe and Logtown. One just above Lapinière landing furnished such an abundance of beautifully preserved forms, showing a typical development of the Texan phase of the Lower Claiborne, that it left no doubt of the correctness of the Monroe label.

The outcrops are all small, are exposed only at low water and furnished no satisfactory dip observations.

The paleontology of the beds is to be discussed by Prof Harris in a forthcoming Bulletin of American Paleontology.

Outcrops from Monroe to Lapinière landing.—On the west bank about a mile below the Woodworth Lumber Co. mill and near the line between sections 2 and 11, T. 17 N. R. 3 E., a landslip island shows a few feet of Tertiary clay containing greensand and a ledge of calcareous concretions.

At Myatt, the Lower Claiborne clays are exposed beneath the usual succession of material shown in the banks:—The section 200 yards below the ferry is :

Section at Myatt P. O.

		Feet
1.	Fine sandy silt, tinged with red	20
2.	Dark brownish-blue buckshot clay	2
3.	Yellow and grey clayey sand with pebbles scattered irre-	

* Bull. La. Exp. Station Geol. and Agr. part 1, p. 20, 1892.

† Geol. Survey of La. for 1899, p. 82.

gularly through the upper part,—some of fine grey sandstone as large as a man's hat 7

4. Finely laminated dark brown to drab clay with sand partings 15

6. Very dark colored clay with some greensand and large ferruginous concretions, some weighing several hundred pounds. Contains a few indistinct casts 4

Opposite Roselawn landing there is a landslip island, larger but similar, otherwise, to the first outcrop described above. The claystone concretions here are quite fossiliferous.

Lapinière landing.—Near the east bank and just above Lapinière landing there is a small island of dark colored laminated sandy clay exposed at water level. The clay is extremely fossiliferous—and it might be said of it, as of the Monroe material, that so far as the fauna and lithological characters are concerned it might just as well have come from Smithville, Texas, as from the Ouachita river. Among the forms here which indicate the horizon are: *Ostrea falciformis*, *Pyrula penita*, *Belosepia ungula*, *Pleurotoma pagodiformis*, and an abundance of Pleurotomoid forms.

Below this outcrop and on the same side of the river there are a number of little islets of nonfossiliferous, micaceous, ferruginous sandstone, which is about 6 inches thick and shows a great variety of dips.

On the west bank—nearly opposite this and about 100 yards above Lapinière landing—a ledge of ferruginous sandstone 6 inches thick and dipping S. 10° E. is exposed at water level. Nearer the landing the Tertiary clays extend to within 8 feet of the top of the bank. They are overlaid by 2 feet of gravel and the usual buckshot clay with a covering of recent alluvium.

Just above Logtown, is a landslip island exposing grey sandy clay similar to that shown at Lapinière landing. The clay extends 7 feet above the present water level and is capped with a ledge of ferruginous conglomerate.

COCKSFIELD

Preliminary remarks.—This stage is more completely and typically developed in this section than any other place in the state and this has lead to the suggestion, to Vaughan, that he substi-

tute *Caldwell* for *Cocksfield.* Outcrops of this stage extend from Roach landing, the first bluff below Monroe, to Stock landing, where Jackson fossils appear at the top of the bluff.

No dip observations were obtained which could be relied upon, but it is believed that in this section this formation has a thickness of at least 500 feet.

Roach landing.—The outcrop near Logtown is of doubtful age; it may be that no fossils were found there because of the smallness of the outcrop, but at Roach landing the outcrop is large enough to make us feel reasonably sure that the material is to be regarded as Cocksfield.

Section Roach Landing Bluff

		Feet
1.	Light grey to yellow silty sand with a few quartz pebbles	36
2.	Yellow, sandy clay with a thin capping of ferruginous sandstone	2
3.	Light grey, stratified, sandy clay	18
4.	Dark grey clay	5
5.	White to yellow clayey sand capped with iron-stained layer 2 inches thick	10
6.	Covered to water level	3

Bluff at the mouth of Belle Côte bayou.—Continuing down the river, the next bluff is just below the mouth of Belle Côte bayou, near the Ouachita-Caldwell parish line.

Section at Mouth of Belle Côte Bayou

		Feet	In.
1.	Covered	20	0
2.	White to yellow, irregularly stratified sand	17	0
3.	Ferruginous sandstone occupying line of unconformity between 2 and 4	0	3
4.	Laminated, white to brown, fine clayey sand. Surface covered with lemon-yellow scales	8	0
5.	Ferruginous concretions with much pyrites and a few faint plant impressions	0	6
6.	Dark brown, lignitic clayey sand	2	0
7.	Dark drab clayey sand showing bedding planes in upper portions	14	0

8.	Finely laminated, dark drab clayey sand containing some vegetable matter	18	0
	Water level.		

Castor landing.—Two exposures are afforded here, one just above the landing and another about a third of a mile below. At the lower one, a point, evidently formed of a number of landslip masses, juts well out into the river. It is composed of irregularly bedded black clay with sand partings, and calcareous concretions exhibiting a cone in cone structure.

Section at Castor Landing

		Feet
1.	Weathered surface layers	3
2.	Light grey to drab clay with sand partings	1
3.	Coarse cross-bedded sand	3
4.	Alternate beds of laminated, leaf-bearing, drab colored clay with sand partings and coarse cross-bedded sands.	8
5.	Coarse white and yellow sand with occasional thin lens shaped masses of clay	10
6.	Laminæ of drab colored clay separated by thicker sand partings	1
7.	Coarse cross-bedded white sand	3
8.	Laminated, chocolate colored clay with white sand partings and poor plant impressions	3
9.	Very dark clay breaking off in large irregular fragments.	3
10.	Very irregularly bedded, yellow and white sand, here and there darkened with carbonaceous matter	20

Lone Grave bluff.—On both Lockett's and Hardee's maps Lone Grave bluff is placed about 3 miles too far to the south. As seen from the river it shows four ridges—the northernmost one being the highest and having on its summit the grave from which the bluff received its name. In order down the river, the crests are 150, 135, 120 and 110 feet at low water.

Section at Lone Grave Bluff

		Feet
1.	Rather coarse red to white sand	10
2.	Laminated light brown clay with sand partings, the clay containing faint plant impressions	120
3.	Laminated lignitic clay with fine white sand partings	20

About a quarter of a mile below this section irregularly bedded white sand with irregular layers of brown clay appear beneath the black clay.

Columbia.—The railroad sections here have been described in the report of this survey for 1899, pp. 80–81. Two miles above Columbia near old Ferry landing the following section is shown :

Section at Old Ferry Landing

		Feet
1.	White and yellow fairly coarse sand showing only a slight trace of bedding and containing a few concretions	65
2.	Light brown, laminated sandy clay with plant impressions	20
3.	Very dark colored clay containing lignitic material and, near the top, good leaf impressions	30

Home landing.—The small bluff just above the creek at Home landing shows 5 feet of light brown laminated clay, about 15 feet above water level, similar to that seen at Columbia.

Stock landing.—The high bluff at the mouth of Boggy bayou furnishes a very good section of this formation and also shows the contact between it and the Jackson.

Section at Stock Landing

		Feet
1.	Fossiliferous Jackson marl, partly covered with vegetation	20
2.	Drab to yellow sandy clay	20
3.	Faintly laminated light yellow and brown clay with faint leaf impressions	8
4.	Massive grey sandy clay	8
5.	Brown stratified joint clay with selenite crystals	7
6.	Dark colored sandy clay containing much lignitic matter	2
7.	Brown to yellow unstratified sand	12
8.	Dark brown clay with slight greenish tinge. Surface covered with small selenite crystals	6

Exposures below Stock landing.—Beds of this stage appear at the base of the Gibson landing section and at Grandview bluff and Bunker hill ; see these sections given below.

JACKSON

Preliminary remarks.—It was from fossils collected in this region that the Eocene was first definitely recognized in Louisiana.* It has also furnished the type specimens of *Basilosaurus* (*Zeuglodon*) *cetoides*† *Cardium nicolleti*,‡ and *Haminea grandis*.§

The Jackson is now known to extend along the Ouachita from Stock landing to Carter landing (the present site of Enterprise P. O.). The beds are extremely fossiliferous and the outcrops well exposed, and we regard it as the best Jackson section yet found.

The fossiliferous Jackson bed which caps the bluff at Stock landing was traced around the hills and connected with the outcrop at Gibson landing and this in turn with Grandview bluff. This proved the lignitic clays at the base of Bunker hill (see section given below) to be the equivalent of the beds below the Jackson at Stock landing and established a dip of about 50 feet per mile in that direction. Calculations from this dip observation indicate the thickness of this formation in this section to be 500–550 feet. Stratigraphically the outcrops at Stock landing, Gibson landing, Grandview bluff and Bunker hill are to be regarded as lower Jackson; that at Wyant bluff as middle and those at Danville and Carter as upper.

Gibson landing and vicinity.—The fossiliferous layer capping the bluff at Stock landing can be readily traced around the hill to the valley of a small creek between the two landings. The collecting in this valley is extremely good.

Section along road at Gibson Landing

			Feet
Jackson	1.	Stiff, yellow, calcareous clay containing only a few poor impressions of oysters	75
	2.	Shell marl weathering into a black waxy soil	25

*Conrad. Jour. Phil. Acad. Nat. Sci., vol. 7, 1834, p. 120.

† Harlan. Trans. Am. Phil. Soc., vol. 4, New Series, 1832, p. 403.

‡ Conrad. Proc. Phil. Acad. Nat. Sci. for 1841, p. 33.

§ Aldrich. Geol. Surv. Ala., Bull. No. 1, 1886, pp. 35–36, Pl. III.

Transition	3.	Doubtful. Irregular masses of shell matter are here scattered through a grey or drab clay but whether the shells are really *in situ* or represent masses which have slipped from the bed above could not be determined	20
Cocksfield	4.	Massive, calcareous grey or drab clay without fossils	16
	5.	Laminated drab clay	3
	6.	Yellow to drab massive sandy clay	13
	7.	Unexposed to water level	55

Section of Bluff Below Gibson Landing

			Feet
Jackson	1.	Fine yellow sand with well preserved shells, to top of bluff	20
Transition	2.	Slightly stratified calcareous drab to dirty grey clay without fossils	20
Cocksfield	3.	Irregularly laminated drab clay with poor plant impressions; becomes lighter and more sandy above	18
	4.	Irregularly bedded drab sandy silt containing lignitized wood	15
	5.	Dark drab, laminated sandy clay mottled with yellow and containing large iron stained calcareous concretions	20
	6.	Covered-talus and landslips to water level	35

Grandview bluff and Bunker hill.—These are perhaps the best known bluffs along the river and are particularly noteworthy to the paleontologist and collector because of the extremely large and well preserved *Haminea grandis* which occur here with other well preserved forms.

Section at Grandview Bluff

			Feet
Jackson	1.	Blue clay containing faint casts and occasional solid shells. Weathers into a very stiff yellow clay......	100
	2.	Grey to yellow sandy marl with some greensand and large calcareous concretions........................	8
Transition	3.	Dark brown, laminated clay mottled with yellow, contains numerous selenite crystals.................	9
Cocksfield	4.	Massive dark grey or greenish-grey, fine sandy clay mottled with yellow. Contains numerous pieces of lignitic material and large grey calcareous concretions....................	33

At Bunker hill there is only a small exposure along the river and it is greatly complicated with landslips. It shows very clearly the manner of formation of the Tertiary ridge-islands between Monroe and Columbia (see p. 156). Near the top of the bluff is a layer of large *Venericardia planicosta*.

At Bunker hill landing the lower layers of the Grandview bluff section become even blacker and have in places the aspect of an impure bed of lignite.

*Wyant bluff.**—This locality was visited in the spring of 1899† but on account of the high stage of the water only a small portion of the outcrop was seen. At low water, beds are exposed which afford better collecting than the outcrops at Grandview and Bunker hill. The material here shows numbers of the large *Venericardia planicosta* which are common in the upper Bunker hill section and none of the *V. alticostata* which are so abundant in the lower bed at that place.

Section at Wyant Bluff

		Feet
1.	Thin, alternate layers of brown clay and very fine grained grey to yellow sand, which are quite similar to the material in the upper part of Bunker hill....	25

*Given Myatt landing on Sheet No. 32, Ouachita River Survey, 1896.

† Geol. Surv. La. Rept. for 1899, p. 93.

2. Blue clay with pockets of shells; weathers first to a brown or dark drab clay and finally to yellow....... 42

At Neathery woodyard there is a small outcrop of fossiliferous blue clay with large calcareous concretions.

Danville.—The bluff on the Caldwell-Catahoula parish line is quite fossiliferous.

Section at Danville Landing

		Feet
1.	Covered to top of hill..............................	70
2.	Light yellow, quite fossiliferous clay, containing large selenite crystals and large concretions	20
3.	Fossiliferous blue clay weathering dark brown to yellow. The shells are scattered through the whole mass and occasionally occur in thin beds with light brown sand	30

The fossiliferous beds in layer 3 show a very great dip, S. E., 1:6. The upper layers, however, do not appear to have such an extravagant dip and the great dip in the lower bed is probably due to landslips.

Carter landing.—Just above Carter landing is a small landslip island which exposes at low water a fossiliferous blue clay with a well marked Jackson fauna.

OLIGOCENE

VICKSBURG

No beds of this age outcrop on the river but they are exposed in the hills a short distance from it. These outcrops are discussed by Prof. Harris in special report No. 1 (q. v.).

GRAND GULF

Preliminary remarks.—Between the Jackson outcrop at Carter landing and the first outcrop of Grand Gulf, at the mouth of the Boeuf river, the river does not touch the hill lands and there are no exposures of the older formations. The material at Cash bluff, at the mouth of the Boeuf, is typical Grand Gulf but how much it is above the base of that formation it would be difficult to say. At Catahoula shoals the recent boring of the U. S. Engineers does not appear to have reached the Vicksburg at a

depth of 197.5 feet.* This boring, with the height of the hills at Harrisonburg, indicates that the formation has a thickness somewhat greater than 300 feet.

Cash bluff.—The upper end of Sicily island, just below the mouth of the Boeuf shows a three-ridged bluff, the central ridge being the highest. The section of this is as follows:

Section at Cash Bluff

		Feet
1.	Unexposed to top of the hill. The hillside is covered with chert and quartz pebbles	20
2.	Yellow clay and sand	12
3.	Very dark colored clay	2
4.	Fine grey to yellow sand	11
5.	Hard sandstone	2
6.	Brown to dark drab clay	7
7.	Yellow clay with thin plates of iron	8
8.	Brown clay	5
9.	Grey sandstone (has been quarried to some extent)	11
10.	Obscured by talus but from the fragmentary exposures it seems to be a slightly sandy, yellow clay with bands of brown clay about a foot thick	13
11.	Dark brown clay	4
12.	Indurated, cross-bedded fine grained sand	6
13.	Green and brown clay	6
14.	Dark brown clay; not sharply separated from 15	5
15.	Green clay	6
16.	Covered	10
17.	Fine grained white sandstone	2

Layer 17 here shows a dip west of south.

The bluff, near Catahoula shoals, is about 60 feet high and shows several ledges of sandstone.

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* Final Report on the Survey of Ouachita and Black river, Arkansas and Louisiana, 57th Cong., 1st Sess. House Ex. Doc., No. 448, p. 126, 1902.

PLIOCENE AND RECENT

BANK EXPOSURES

General characteristics of the deposits.—The following generalized section of the bank deposits indicates the succession and characteristics of the bank deposits in this portion of the river:

Generalized Section of the Ouachita Bank Deposits Between Monroe and Harrisonburg

		Feet
1.	Light colored silty clay commonly reddish	5–15
2.	Buckshot clay; black to dark reddish brown commonly stratified and with white calcareous concretions, sometimes with fragments of wood and fresh water gastropods	10–20
3.	White and yellow sand, above Columbia commonly containing chert and quartz pebbles	15–25

The gravel bearing sands, exposed in the banks from Monroe to Logtown, are quite similar to the material in the nearby Lafayette gravel train, but whether it is continuous with that deposit or represents a redeposition of material of that age cannot be proven by the information now in our possession. The gravel is commonly rather small but one large quartzite bowlder, weighing about 125 pounds, was seen near Myatt P. O.

On the whole, these lower deposits are quite similar to the beds exposed in the Bayou Macon hills and seem to indicate that the material which may be regarded as recent alluvium is of no considerable thickness in this section.

Sections.—The following sections at particular localities may illustrate the general section given above:

Section at Brooks Landing

		Feet
1.	Light colored, sandy silt	7
2.	Dark reddish brown to dark dirty yellow buckshot clay, containing numerous white calcareous concretions	16
3.	Medium white sand, containing in basal portions numerous small chert and quartz pebbles	21

Section Above Sillar Landing

		Feet
1.	Light red sandy silt	15
2.	Dark reddish buckshot clay	10
3.	White and yellow sand becoming clayey near the top	20

Section Near Sawmill Landing

		Feet
1.	Light red silty clay	13
2.	Buckshot clay, black below, dark red above, stratification well marked	17
3.	Red sandy silt	14

EXPOSURES AWAY FROM THE RIVER

Cane hill.—Cane hill is a small, low-lying, isolated hill-mass about two miles east of Call landing, on the line between Sec. 16 and 21, T. 14 N., R. 4 E. It is about a quarter of a mile long, north and south, and a hundred yards broad. Its two highest points are respectively 22 and 24 feet above the level of the surrounding bottom land. The surface soil is a somewhat sandy, mottled yellow and grey clay, containing a few chert and quartz pebbles and is quite different from the surrounding soil. A well on the side of the hill, 15 feet deep, passed through mottled grey and white clay and stopped in water-bearing white sand. The material shown in the well and on the surface suggests the lower beds of the bank section and the hill seems quite analagous to the Bayou Macon hills. This is reported to be the only hill land between Bayou Lafourche and the Ouachita.

APPENDIX

NOTES ON INDIAN MOUNDS AND VILLAGE SITES BETWEEN MONROE AND HARRISONBURG

Myatt P. O.—There is a shell-heap at this point between the store and Bayou Cheniere au Tondre.

Another shell heap occurs just across the bend of the river, near Lapinière landing. Here I found fragments of pottery and bones, among which was a human jaw bone. Large finds of bones are reported just after the flood of 1882 when this place was uncovered.

Minden Hall landing.—At Minden Hall landing there is a small mound about 3 feet high and 50 feet in diameter. On the ground around it there are numerous pot-shreds and mussel shells and a nearby road-cut exposes a number of bones.

Hogan landing.—Two mounds near the river, about a quarter of a mile above the store. One is directly on the edge of the bank though well removed from the river by a large bar. This has been cut into by the river on one side and by the road on the other and its symmetry somewhat destroyed. It is a truncated pyramid mound about 15 feet high and 100 by 50 feet on the top, and with a slope of about 30 feet. The second mound is about 225 feet from the first and is 14 feet high. It is rudely circular with a flat top 75 feet in diameter and a base 175. Both mounds have been used as graveyards; one for whites and the other for negroes.

Wyant bluff.—The top of this bluff was evidently used for an Indian camp-site. The ground is covered with unios and fragments of pottery, and where a section is afforded by a landslip, animal bones and pottery are found mixed with the recent shells.

Pierce landing.—Low mound about a quarter of a mile from the river. The soil is very black and fragments of pottery and bones are reported to have been plowed up. Several whole pots are also reported from this place.

Cottingham landing.—Mound 3 feet high and 40 feet in diameter exposed in cross section on the bank of the river. No relics are reported.

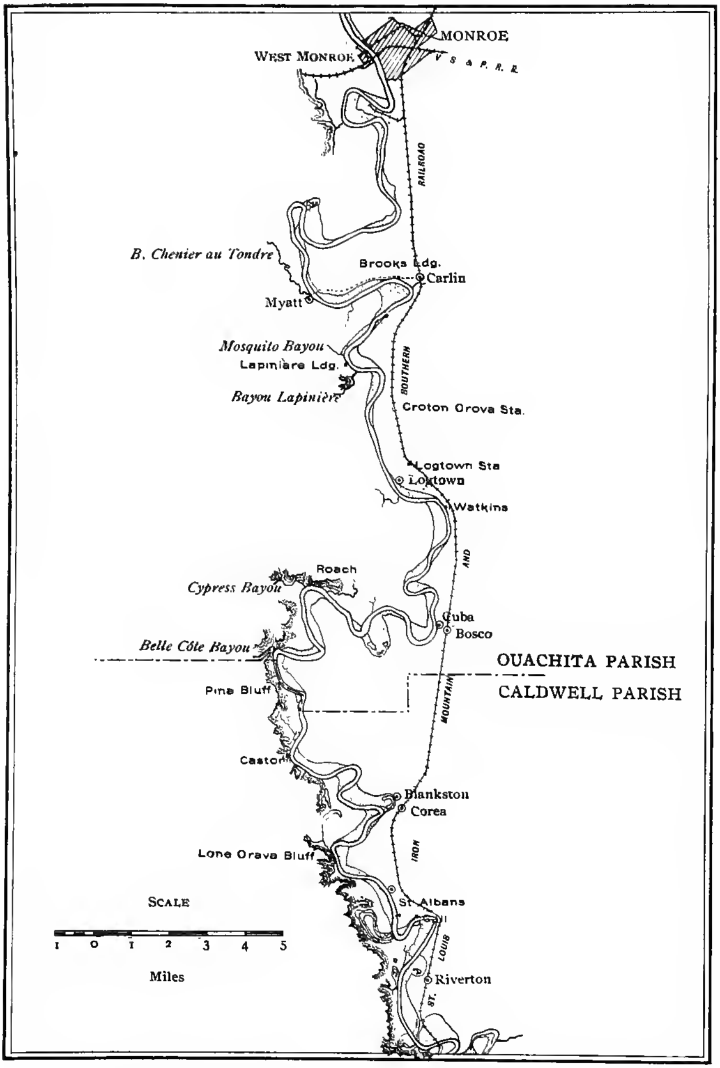
Sec. 21, T. 11 N. R. 5 E.—Small mound on Horseshoe lake about 6 feet high.

Carter landing.—About half a mile below Carter landing is an old Indian camp-site ; the ground is covered with unios, stones, fragments of pottery and partially shaped implements.

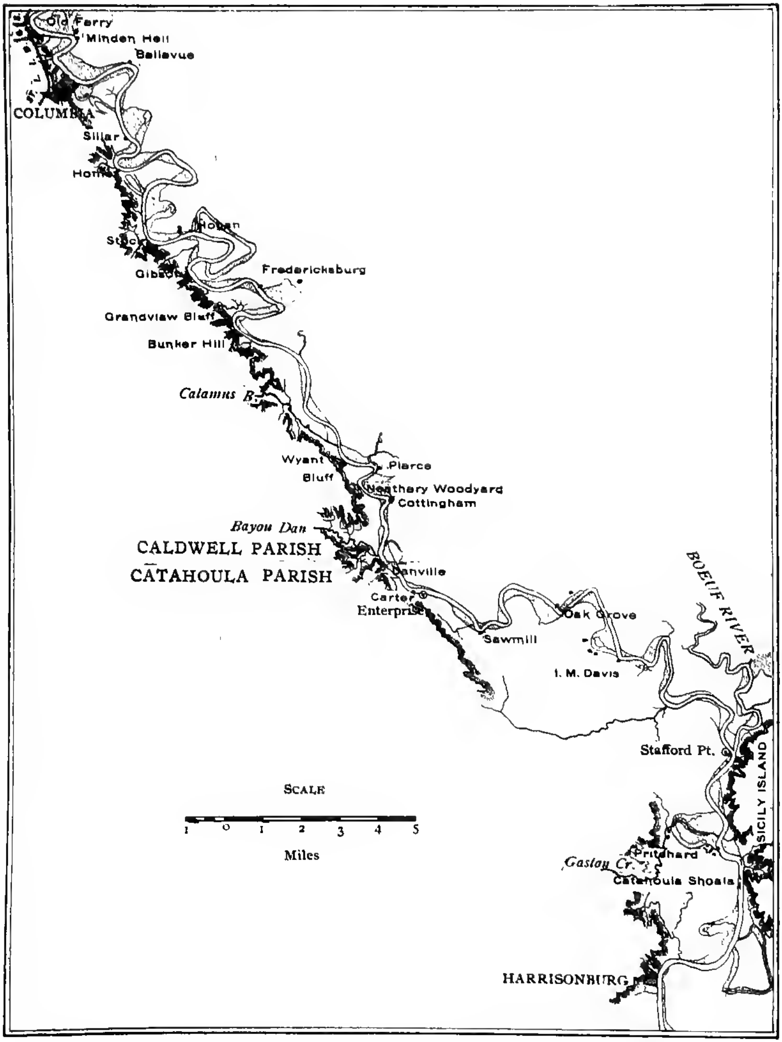
Oak Grove landing.—At this place a narrow ridge of grey loam follows the river northeast. The ridge is about 6 feet above the surrounding land and has once been cultivated. Just beyond this old field, and a little over a quarter of a mile from the river, is a more marked and regular elevation than the other elevations along the ridge. It is about 50 feet in diameter and 3 feet high and on the surrounding land—in material rooted up by the hogs—pottery and mussel shells are common.

Big lake.—Half to three-quarters of a mile northwest of I. M. Davis landing is a group of mounds on Big lake. A sketch map of this group was made but it has since been found that they are shown on Sheet No. 34, Ouachita River Survey, 1896, to which the reader is referred. The writer saw only three mounds though five are represented on this map. The first two mounds, seen in following the road from Davis landing, are rudely rectangular and belong to the truncated pyramid type; one is 13 feet high and 15 by 50 across the top and has a slope of 25 feet, the other is 5 feet high, 38 by 38 feet across the top, with a slope of 20 feet. The side of one bears S. 27° W. and of the other S. 36° W. The northermost is oval 4½ feet high, 38 by 45 feet on top, with a slope of 15 feet. Its major axis extends S. 36° W.

Pritchard landing.—Group of mounds below mouth of Gaston's creek contains three large truncated pyramid mounds and eleven smaller rounded oval mounds. The mounds occupy a slightly elevated piece of ground, and two are on the very edge of the second bank. The largest is 36 feet above the level of the surrounding ground and is 150 by 60 feet across the top. The second, northwest of the first and along the edge of the bank, is 30 feet high. Between these two large mounds is a circular embankment 75 feet in diameter. The third large mound, situated south of west of the other two, is 25 feet high. Between the second and third, forming an irregular arc of a circle, are seven small mounds. The location and general character of this group is given on Sheet No. 36 Ouachita River Survey, 1896.



MAP OF THE OUACHITA RIVER FROM MONROE TO COLUMBIA
Compiled from Maps of the Ouachita River Survey.



MAP OF THE OUACHITA RIVER FROM COLUMBIA TO HARRISONBURG
Compiled from Maps of the Ouachita River Survey.

SPECIAL REPORT

No. V

IMPROVEMENTS IN LOUISIANA CARTOGRAPHY

BY

G. D. HARRIS

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IMPROVEMENTS IN LOUISIANA CARTOGRAPHY

PRESENT CONDITIONS WITH SUGGESTIONS

NEED OF ACCURATE MAPS

Maps for geological purposes.—In our previous report we have explained at some length the benefits to be derived from well constructed topographic maps. The immigrant, the traveler, seeking health, enjoyment or wealth ; the student of geography, botany, geology or entomology ; the teacher of natural science in or out of the state, even the inhabitant himself if he would visit other parishes than his own, knowingly and economically : each and all must have access to well constructed topographic maps, or lose much time in annoying and useless inquiry. To anything like refined geologic work, topographic maps are indispensable. This was early recognized by the U. S. Geological Survey, and hence a large share of the annual appropriation made by Congress for survey work goes to the topographic division. We have recognized the fact, as have other state surveys, that the cheapest, best and most expedient method of obtaining such maps is by coöperation with the National Survey. The conditions of coöperation we have already stated in our report of 1899. When such maps shall have been prepared, the areal geologist and stratigrapher, as well as the mapper of soils, can proceed advantageously with their respective work. We already know in a general way the distribution of the main geological formation of the state. To go farther in areal work without better maps is a waste of energy and public funds.

Doubtless the present Legislature will provide ample means for a good beginning in the construction of maps on the usual scale, viz. ; about one inch to the mile. The U. S. Geological Survey will furnish an equal amount and hence geological work can be resumed and carried on advantageously.

Detailed maps.—There will always be areas of special interest here and there that will require geological maps of far greater

detail than the ordinary one inch to the mile map. These the state survey can construct for itself, using as starting points the triangulation stations and bench marks established by the National Survey.

THE ORDINARY LAND SURVEYS

The geologist is often under great obligation to a local or parish surveyor who has prepared maps of a limited area or who is able to show the position of township, section or quarter lines and corners.

Unfortunately for the representation of such an area on a finished geological map, the exact bearings of the lines are unknown, since only crude approximations can be obtained by the compass methods now generally in vogue. Different surveys give naturally different sizes and shapes to the sections composing a township. This we may perhaps admit is of no serious consequence to reconnaissance geological work, such as has been done in the state heretofore. But let the geologist work up ever so faithfully the details of several adjacent townships, basing his own measurements on distance and direction from quarter-quarter or section corners and finally attempt to map his area on any given projection, for example the polyconic, and then see what a vast number of uncertainties arise. We speak with feeling and experience on this subject.

INSTRUMENTS

The ordinary compass.—Little need here be said regarding the manipulation of this instrument and the results obtained, the matter having been spoken of at some length in our previous report. As an amusing instance in modern "business" methods, however, we cannot forbear giving our recent experience in one of the largest instrument factories in this country. Having admitted the inadequacy of the common compass for anything but the merest reconnaissance work, the salesman, with a knowing glance said: "I know all that, but then they *sell* well in some places."

Railroad compass.—We have been greatly pleased with the performance of a very cheap instrument of the type shown by

Fig. 16.* It has in addition to the usual needle a graduated limb reading by a vernier to single minutes. We have proved by experience that with beginners the 3 angles of a triangle will "close" within from 1′ to 5′, on an average; and, with more experience and more readings of each angle, the average error can be brought below 1′. The particular instrument we happened to have was by Queen & Co., of Philadelphia, though other makers list something more

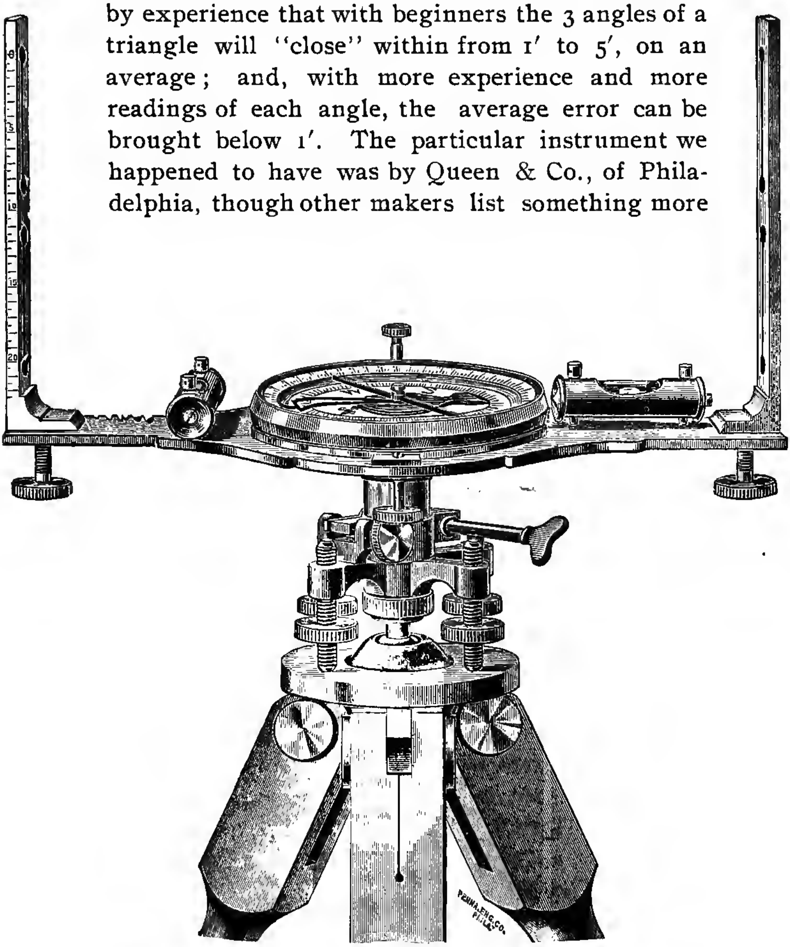

FIG. 16.—RAILROAD COMPASS

or less similar. The catalogue price is $45, tripod and all. If long distances are to be sighted, the telescopic attachment shown

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* This and the following two figures were kindly loaned for this work by Queen & Co., of Philadelphia, Pa.

by Fig. 17 comes very convenient. This, too, is carried by nearly all dealers in surveying instruments.

The possession by this compass of a horizontal limb with vernier reading to minutes gives it a manifold superiority over the common "plain" or "vernier" compass.

When cheapness, lightness and efficiency are concerned it is difficult to see how a better instrument could be constructed for ordinary country service.

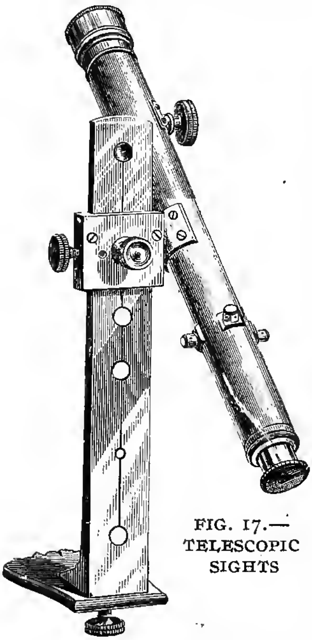

FIG. 17.—TELESCOPIC SIGHTS

Transit.—The railroad compass fails in but one respect from fulfilling the requirements of the land surveyor: It determines angles or relative directions, but is no better than the plain compass for determining absolute direction. The true direction of one line is assumed or approximately determined by readings of the compass needle, then the rest are determined relatively to it. The transit, however, with a vertical as well as a horizontal limb can be used to advantage to determine absolute direction so far as the earth's axis and meridians are concerned. See Fig. 18.

A light transit, of moderate cost, with vertical and horizontal limb, a fair knowledge of spherical trigonometry, a table of refraction and a Nautical Almanac should be included in the equipment of every land surveyor. The appearance of an instrument of this kind is given herewith. To be sure, if the surveyor cares to keep in adjustment a solar attachment and does not mind the extra expense, he can solve instrumentally the problem of meridian determination with facility and dispatch. But the calculations required without the attachment can scarcely be called tedious or long, especially after a little practice. (See any manual of surveying or even a good catalogue of surveying instruments.)

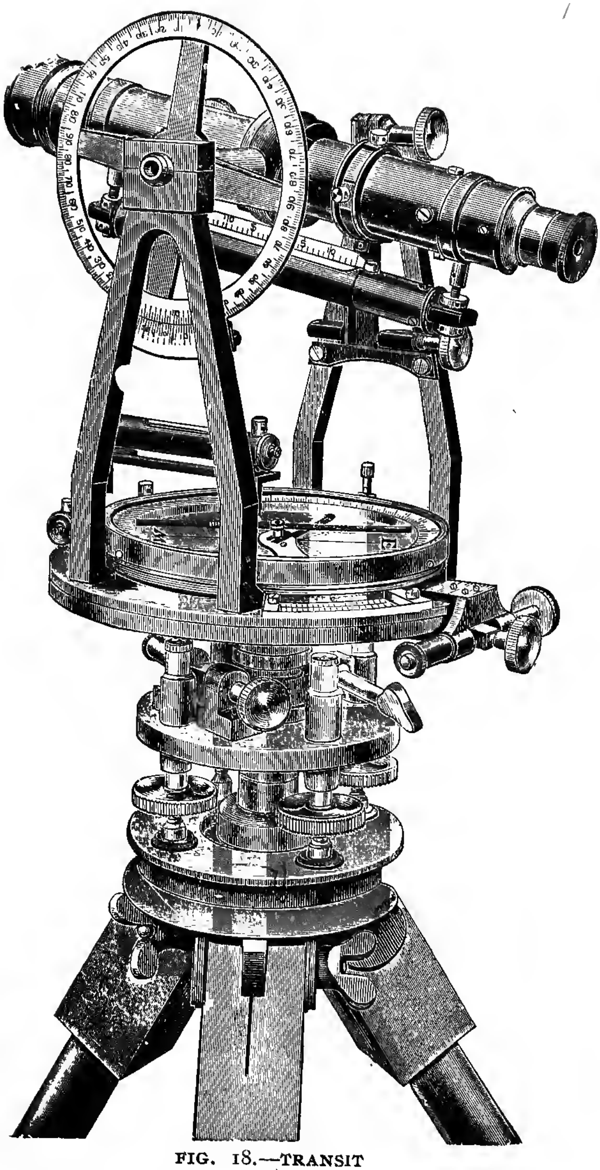

FIG. 18.—TRANSIT

FIELD WORK

ESTABLISHMENT OF MERIDIAN LINES

Prefatory remarks.—Little need here be added to our remarks on the same subject three years ago. The main object of the work is quite obvious, viz.: to have a substantially marked line, one at least in each parish, that may serve as a reference meridian for determining magnetic declination. In carrying out this work, no attempts have been made at refined, geodetic work. It is scarcely ever possible to secure an open stretch in public grounds over a few hundred feet in extent. Such short distances are not condusive to a refined class of work, but still, they are more convenient for ordinary compass sighting and no error need be made in establishing the line, sufficient to affect the readings of any compass or even magnetometer.

Our own method of procedure has been explained heretofore. A large bull's-eye lantern with a moderately fine grating or even a few slim, straight brads before it, so placed that near elongation Polaris' azimuth position can be recorded in reference to slot or brad 1, 2 or 3, etc., is quite satisfactory for a target. The spacings of the target at a given distance from the transit represent a certain number of seconds of arc. A number of readings extending from, say 20 minutes before to 20 minutes after elongation can be made with the telescope upright and reversed. These can all be quickly reduced to elongation, the same as when a series of micrometer readings have been made.

The instrument we have used for all the work during the past three seasons is one of Buff and Berger's Tachymeters "No. 1g." It is shown on page 183 (Fig. 19).

Other azimuth lines.—A large amount of refined geodetic work has been done along the Mississippi, Red, Ouachita and other rivers and bayous. The surveyor living in the vicinity of triangulation stations along the Mississippi can obtain information regarding direction or azimuth from such stations to other known points by writing to the Superintendent of the Coast & Geodetic Survey, Washington, D. C. Information regarding stations on other rivers and bayous can be had by writing to U. S. Engineer's Office at St. Louis, Mo.

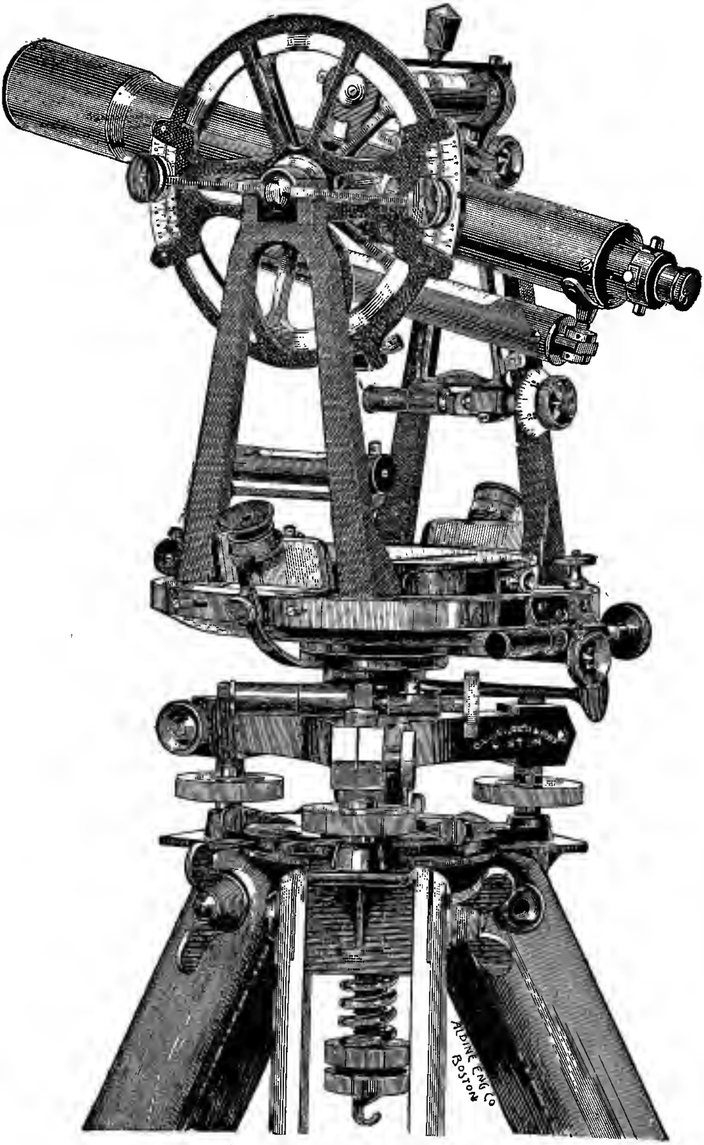

FIG. 19 —TACHYMETER

ARCADIA

Plate XL, Fig. 1.

General location.—Court yard, east of the Court House; also one marker 70.9 feet south of the south track of the V. S. & P. R. R.

Monuments.—Old and very hard concrete posts sunk nearly flush with the ground into a mass of fresh concrete.

N is only 55.2 feet east of the northeast corner of the Court House. S' is 207 feet farther south, near the road. N' is 58.9 feet north of N and 83.1 feet northeast of the northeast corner of the Court House. It is close to the northern limits of the public grounds. N'' is approximately 715 feet farther north, or 70.9 feet south of the south rail of the V. S. & P. R. R.

Marks.—One-half inch holes, filled with lead plugs.

RUSTON

Plate XL, Fig. 2.

General location.—Across the yards of the State Industrial college; west of the main building; about 106 feet east of the west boundary fence.

Monuments.—S consists of a small, long steel rod inserted in a concrete mass, large and round at base, but cast about one foot square above ground. This is seven feet from the wire fence bounding the yard on the south; 104.9 feet from the southwest corner of the yard. S' is a similar rod inserted in concrete. This concrete is contained in a five-inch sewer pipe, which in turn is sunk nearly flush with ground into a mass of concrete. This marker is 315 feet north of marker S; 249.45 feet from the S. W. corner of the Industrial college and 309.8 feet south of N; N is just south of a cinder path; 174 feet from the southwest corner of the college; 253.7 feet south of N' It is similar to S' but with 12-inch sewer pipe in concrete.

N' is but 215 feet from the north yard fence; 106.7 feet from the corner of college yard; similar to N and S'.

The western end of the college is directed north 23° 8½' east.

Marks—Long pins in concrete.

VERNON

Plate XL, Fig. 3.

General location.—Across Court House yard in front of Court House and extending across the Monroe road 100 yards into an open field.

Monuments.—Ferruginous sandstone blocks varying in weight from 40 to 150 pounds; set in finely broken and finely pounded brick and rock debris.

S′ is 47.2 feet from the S. W. corner of the Court House and 65 feet from the N. W. corner; it is 95 feet south and 14 feet west of a large red oak in the Court House yard.

S is across a highway, by the corner of a fence, 11.5 feet from a pin oak and 140.33 feet south of S′.

N is just across the Monroe road, about where once was an old fence, and 194.3 feet from the N. W. corner of the Court House.

N′ is 306 feet north of N, just south of a picket fence.

Marks.—One-half inch holes sunk in the rocks.

BASTROP

Plate XL, Fig. 4.

General location.—Across the public school grounds, just back of the school house, and extending south into a woods of second growth pines.

Monuments.—Cement filled sewer pipes sunk into the ground nearly flush and secured by a mass of concrete.

S is just south of an opening made for a new street in woods. N is on the southern border of the school grounds, 422.45 north of S.

N′ is near the northern limits of the yard.

Rain prevented accurate measurements to nearby objects and from N to N′. The diagram is only approximately to scale.

Marks.—Slots north and south in end of ¼-inch by 6-inch bolts sunk into cement inside of sewer pipe.

RAYVILLE

Plate XL, Fig. 5.

General location.—Across the Court House square between Court House and jail, and extending northward across the V. S. & P. R. R. track 400 feet into the woods.

Monuments.—Six-inch by 30-inch sewer pipes filled with cement and sunk into a mass of concrete.

S is 18.1 feet north of the south yard fence, N is 221.4 feet farther north, but 2.4 feet south of the north yard fence; 79.2 feet from the Court House; 91.38 feet from the jail.

N′ is outside of the yard, 55.19 feet to the north of N and near the limit of the railroad property, or 72.3 feet south of the middle of the south rail of the V. S. & P. R. R. N″ is in a swampy woods 473.1 feet north of N′.

Marks.—A north and south slot in the end of ½-inch by 6-inch bolts sunk into cement in center of tile flush with surface of cement.

The V. S. & P. R. R. here has an average azimuth of about 95° 11′ 35″. It is intended to be straight, but the rails swing to and fro considerably, as seen through a telescope.

WINNSBORO

Plate XL, Fig. 6.

General location.—Across the Court House yard, passing between the jail and Court House, missing the latter by only six feet; continued in the unfenced, somewhat wooded, pasture land to the north.

Monuments.—S is a large uncut Grand Gulf sandstone post (about 150 lbs.), sunken in the ground nearly flush with the surface and secured by a mass of concrete. This is within about three feet of the south yard fence.

S′ is 293.45 feet farther north, very close to the north fence. It is similar to S. N is a sewer pipe filled with concrete and sunk nearly flush with the ground in a mass of concrete. It is 233.84 feet north of S′. N′ is similar to S and S′; 321.05 feet north of N; to the northwest, 18.5 feet is a large gum, to the north a water-oak 37 feet away, and to the northeast, 37 feet, is a locust. The middle of the bridge over the bayou close by is on the line.

Marks.—One-half inch holes drilled into the sandstone; or, in the case of N′, the usual iron rod just projecting from the center of the concrete within the sewer pipe.

NEW IBERIA

Plate XLI, Fig. 1

General location.—On Avery's island (Petite Anse), N, just outside of yard, south of gate on path leading to salt mine; S, just north of a small stream bed surrounded by small forest trees, in pasture lands, also golf links.

Monuments.—Solid concrete blocks, from 1½ to 2-foot cubes.

Marks.—Small copper rods sunk in about flush with the upper surface of the concrete.

FRANKLIN

Plate XLI, Fig. 2.

General location.—In a pasture, just across the Teche, opposite the wharves. Both N and S are within about five feet of the fence surrounding the pasture. S is 160 feet east of the bank of the bayou.

Monuments.—Two sandstone posts sunk in the ground about three feet and projecting four and eight inches.

Marks.—Holes filled with lead plugs. After drilling the hole in N, it was found that there was another old hole in the end of the post, filled with debris. Care should be taken to sight towards the new, or western hole containing the lead; as heretofore described.

OPELOUSAS

Plate XLI, Fig. 3.

General location.—Public cemetery, about one-half mile east of the Court House. N is 17.3 feet from the northern fence; and 131.6 feet is the distance from the place where the meridian line passes through the northern fence, to the northwest corner of the cemetery. The line passes 23 feet east of a large oak tree. M is 315.65 feet from N and is but 14.25 feet north of the south fence. S is just on the south side of the fence on the opposite side of the road. The line crosses the southern cemetery fence 182.5 feet from the southwest corner.

Monuments.—N and M are marked by marble slabs or posts

6x8x30 inches, set upright in a hole 24 to 30 inches in diameter, and about 30 inches deep in which concrete was poured and firmly packed until the whole mass was even with the surface of the ground. S is a syenite post, shorter but larger and heavier, also set in concrete.

Marks.—Drilled holes filled with lead plugs.

HOUMA

Plate XLI, Fig. 4.

General location.—On Catholic Church grounds, south of present cemetery, though on lands that will eventually be used for cemetery purposes; between Goode and Grinage streets; with measurements as given in Fig. 4.

Monuments.—Marble posts 6x6 inches square by 2½ to 3 feet long, set on and in a mass of concrete 2½ feet square above, or flush with surface, and 1½ to 2 feet square at base.

Marks.—N and S are marked by short copper rods inserted vertically in the marble posts and firmly leaded in. On M simply a sunken line indicates the place where the meridian passes.

ST. MARTINSVILLE

Plate XLI, Fig. 5.

General location.—In front of the Catholic Church. M is 13.45 feet west of the statue directly in front of the church, N is 155.7 feet farther north and 34½ feet from Main St., S is 256 feet south of M and 9.8 feet from east fence and 51 feet from middle of Port St.

Monuments.—Masses of concrete between 2½ and 3-foot cube sunk even with the surface of the ground, and containing (S and N), marble slabs 7x12x14 inches let into the soft concrete edgewise till their upper surfaces remained flush with the upper surface of the concrete and of the ground. M is a 5x5x30 inch marble post set in concrete.

Marks.—Holes with lead plugs.

LAKE CHARLES

Plate XLI, Fig. 6.

General location.—On the grounds of the Lake Charles College, N is just south of the northern boundary fence; M is about half way between the college and the janitor's lodge, by a young China tree just south of an east-west open ditch; S is just north of the south fence.

Monuments.—Marble posts about 4x4x30 or 36 inches imbedded vertically in a solid mass of concrete about 30 inches cube and rising but slightly above the surface of the ground.

Marks.—In each post a hole was drilled, in the center of which a small copper nail was placed, and filled with lead.

COVINGTON

Plate XLI, Fig. 7.

General location.—On land of Judge Jas. L. Thompson, about 1/3 mile northward of the cemetery, near the first slight angle or deflection to the westward of the Holmesville road; the old Massy Baker grant.

Monuments.—N is a marble post 6x8x30 inches, set in concrete and projecting two or three inches above the surface of the ground. About 7 feet due north is a granite marker 5x12x13 inches likewise set in concrete. These are near the edge of a thin pine woods, or on the east edge of an old rice field. A wire fence passes between the two.

S is of marble and similarly set, 1203 feet south of N. The granite marker is 6.2 feet to the south. These as indicated in the diagram are close to the Holmesville road just over the fence.

This meridian line if extended 648.5 feet south from S intersects the northeastern boundary line of the Collins tract, 2960.3 feet from the north corner of the same.

Marks.—Small holes drilled in the tops of the monuments and markers.

CAMERON

Plate XLI, Fig. 8.

General location.—Across the garden and lands of Dr. Isaac Bonsel, west of his residence, passing about 7 feet west of his

office. The south end is perhaps 150 yards N. E. of the Court House.

Monuments.—Marble posts about 4x5x30 inches set in oyster-shell concrete. S is 10 feet from road fence; 2.9 feet from Bois d'arc hedge; 32.7 feet from S. E. corner of office; 26.5 feet from S. W. corner of office; 29.16 feet to S′. S′ is 7.02 feet to S. W. corner of office; 29.16 feet north of S. N is 773.52 feet north of S. N′ is 2.8 feet north of a fence or 779.81 feet north of S. The markers S′ and N′ are set in concrete but are only 18 inches in length.

Marks.—Small ¼-inch holes sunk in top of monuments.

ABBEVILLE

General location.—In front of Court House; N near north side of grounds, S near south side. Length, 161.54 feet. At S, azimuth to Methodist Church spire, 178° 31″; to S. W. corner of Court House, 241° 45″ (distance 86 feet).

Monuments.—Two brick piers about 1½ by 1½ feet coming up nearly flush with the surface of the ground and capped with Portland cement.

Markers.—Iron bolts projecting but little or none above the cement cap, with line sunken in same.

LAFAYETTE

Stone posts were set in the Court House yard; but it was discovered that local attraction caused serious trouble with the needle; hence these monuments must be taken up and placed in the new Industrial School grounds as soon as the arrangement of the buildings can be determined.

THIBODAUX

Marble posts set in concrete; S on north slope of levee, north side of LaFourche bayou; one-fourth mile west of swingbridge; S′ is just north of the road fence; N is about 600 feet north of S′ and just south of pasture fence; N′ is just north of same fence.

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EXPLANATION OF PLATE XL

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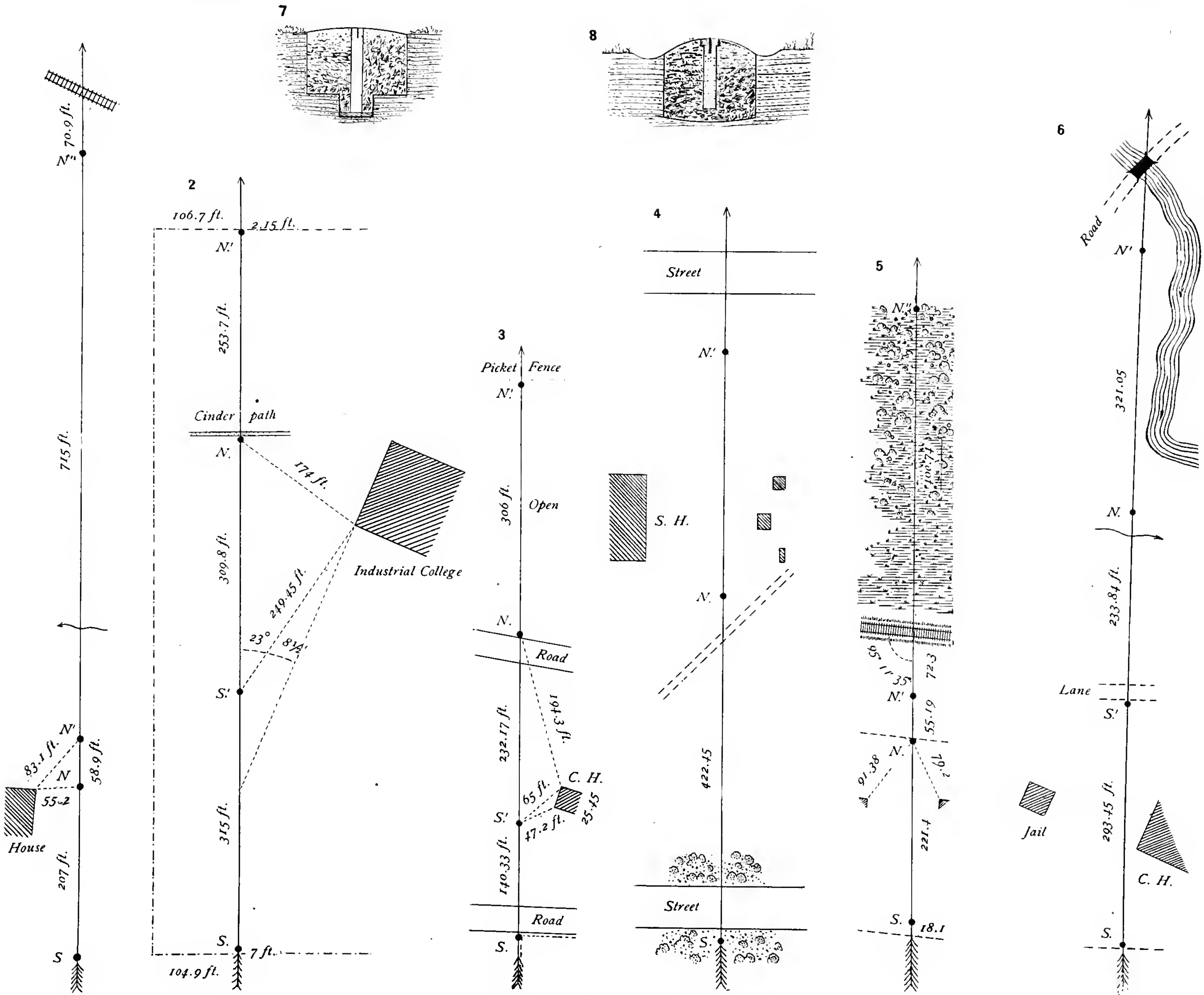

LOCATION OF MERIDIAN LINES

EXPLANATION OF PLATE XLI

EXPLANATION OF PLATE XLI

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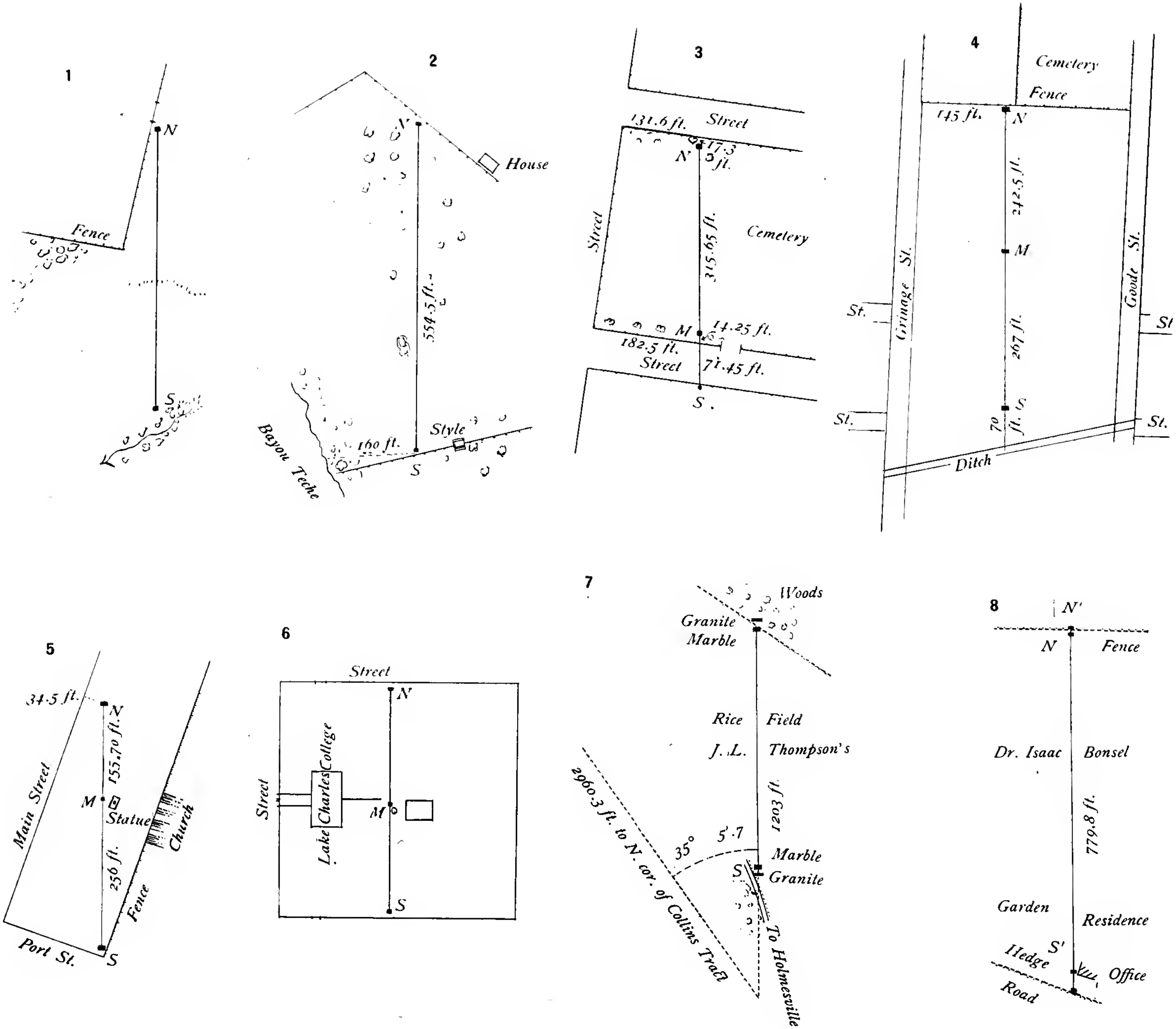

LOCATION OF MERIDIAN LINES

SPECIAL REPORT

No. VI

SUBTERRANEAN WATERS OF LOUISIANA

BY

G. D. HARRIS

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SUBTERRANEAN WATERS OF LOUISIANA

INTRODUCTORY REMARKS

The outsider will doubtless be at a loss to know how it is that Louisiana, a state in the basin and near the mouth of the great Mississippi; a state where precipitation is from 35 to 67 in. annually; a state with thousands of miles of internal waterways; should be in any way troubled for an adequate supply of water at any time in any year. He must reflect, however, that things are not always as they seem at first sight. There are high, sandy hill regions, both east and west of the Mississippi, that, although receiving a large amount of precipitation, lose it quickly by downward percolation. Then, too, in the great coastal clay regions, where water is absorbed but slowly by the underlying beds, and where streams seem in no hurry to carry off any excess moisture, an enormously large demand has recently been made upon the water supply by the thousands of acres of rice fields that require an actual, prolonged inundation if the crop is to be made a complete success. The alluvial lands have an ample supply of water, but it is scarcely ever potable.

There is, then, scarcely a region of any size in the state, that is not vitally interested in a greater or better water supply. Naturally the people have turned their attention to exploiting the subterranean waters. Some have succeeded in obtaining a fair quantity and good quality of water that would flow freely, in other words, they have obtained good artesian wells. Others after expensive operations have found neither an adequate supply nor a desirable quality.

The reasons for success or the reverse are usually not difficult to see where once the mode of occurrence of the underground waters is well understood.

BEARING OF STRATIGRAPHY ON SUBTERRANEAN WATER SUPPLIES

It is easy to conceive of a circular basin occupied by formations of different degrees of permeability, all sloping toward the

center, forming a veritable basin on a large scale. Such an ideal basin is shown by Fig. 20. It would seem that if precipitation took place in this basin and if *B* is a pervious layer or formation, whereas *A* and *C* are impervious, the water falling on *B* would sink in and gradually collect in the center of the basin. Finally if more water was added at *B*, it would eventually fill bed *B* so that in the middle of the basin the water would have a considerable "head" and a hole being drilled at the locality marked "well," would immediately fill with water and overflow. This is the *ideal* artesian well. Whether or not all these conditions are ever fulfilled we are not at present prepared to say. Certainly none of the "deep" or flowing wells in Louisiana belong to this type.

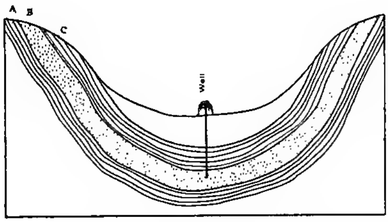


FIG. 20.—THEORETICAL ARTESIAN WELL.

So far as the underground water supplies of this state are concerned, they may best be understood by studying Fig. 21. The hills sloping southward from the Grand Gulf outcrops are composed of sands, gravel and some clay. This is the region where there is an average annual rainfall of nearly 55 in. that must be looked upon as catching the great amount of water that is drawn upon so heavily by the wells in the rice fields farther south.

There are here at least 1400 square miles that serve as a catchment area for this subterranean supply. To be sure, doubtless not one-fifth of the total amount of precipitation ever finds its way into underground passages; for the many important tributaries of the Calcasieu and Mermentau speak emphatically of the quantities of water that quit this country by overland passages. Regarding this section, however, we do not care at present to go into details. We simply wish to use it as typical in explaining the way underground waters occur in Louisiana. In this particular case the overlying impervious layer is the Port Hudson clay, whose origin and history we have already described in Special Report No. I. The pervious layer is the mixed

sands, clays and gravels of the later Tertiary and early Quarternary periods, often included under the name of "Orange sand" or "Lafayette formation." The impervious layers below are the Miocene sandy clays and the Frio and Grand Gulf beds still lower.

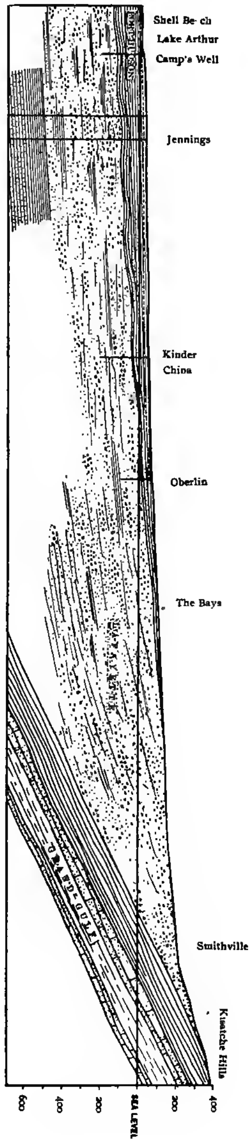


FIG. 21.—DEEP WELL WATER CONDITIONS OF SOUTHERN LOUISIANA.
Dotted line represents hydraulic gradient.

Notice that the water at Oberlin stands in the deep wells at about 60 ft. above the ocean level; at Kinder, 26; at Jennings about 19.7; at Camp's well, 2 miles north of Lake Arthur, 8; and around Lake Arthur, Shell Beach, etc., it overflows pipes elevated a few feet above tide. The water, then, does not exist in the underlying beds as a great level pond, but its upper surface rises up approximately with the slope of the country. The exact distance from the surface of the soil to the surface of the water depends largely on local topography.

This sloping condition of the upper surface of the underlying waters is easily accounted for by assuming a leakage into the Gulf from these beds, a leakage slow to be sure, but sufficient to prevent the waters rising in these wells to their hydrostatic head, *i. e.* the height of their source. The friction of the water along through these sands and gravels is very great. There is therefore no tendency to rise to any considerable height above sea level, even as far south as Lake Arthur. An interesting and instructive illustration of a principle closely allied to the one here involved is given by Professor Davis in the Report of the Geological Survey of New South

Wales Mineral Resources, 1901, p. 457. The figure he gives is herewith reproduced (Fig. 22). "The pipe was filled with sand, coarse shot, and marbles in consecutive order, to represent beds of decreasing porosity. Three vertical glass tubes were luted into holes in the lead pipe, tapping respectively the parts of the pipe filled with sand, shot and marbles. The lower end of the pipe was loosely stopped with a brick to keep the materials in their places. Water was then poured into the upper end of the pipe until the latter was filled, and as the water escaped through the lower end more was poured in to keep the pipe full. The water

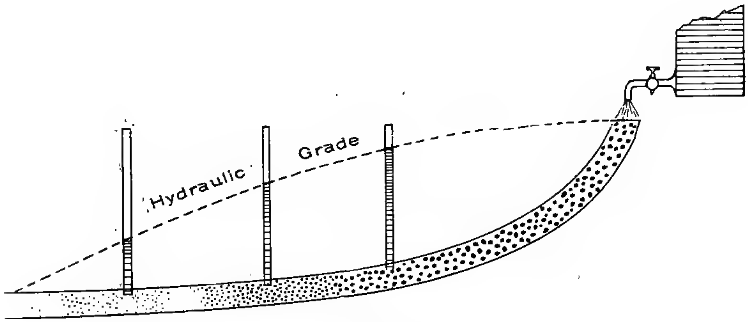


FIG. 22.—EXPERIMENTAL ILLUSTRATION OF CURVED HYDRAULIC GRADIENT.

ascended the three vertical glass tubes, and remained stationary at a certain height in each." If the pipe is small and long, even though nothing be placed within it, the friction of the water along its sides will be sufficient to cause a decided decline in the surfaces of the separate vertical tubes very much as shown in the above figure, though the upward curve in the hydraulic gradient will no longer be noticeable.

These statements we believe will suffice to show the intimate relationship between the subterranean water supply and the way the underlying formations occur in a given region. Any rational prediction, therefore, of the occurrence of artesian, or deep well water, must necessarily be based on a thorough knowledge of the stratigraphy of the region concerned. Plate II, of Special Report No. I, gives a very general idea of the strati-

graphy of the State of Louisiana. It will suffice to show the futility of expecting the same underground water conditions, say at Ruston, as are met with at Alexandria or Opelousas or farther south.

The deep well supply at Ruston is doubtless from the upper Lignitic beds; at Alexandria, from the Cocksfield beds; at Opelousas and to the south, from the Lafayette beds. The first are represented on Plate II by coarse diagonal lining; the second by very fine diagonal ruling; the third by black spots on a white back ground.

TOPOGRAPHIC FEATURES OF LOUISIANA

Intimately associated with the stratigraphy of a region and its bearing on the occurrence of underground waters is the subject of topography, or the surface features of the land. Louisiana is highest in its Grand Gulf territory, *i. e.* its northwest central portion. Hills rise to the height of about 450 A. T. and considerable tracts are above the 400 ft. contour. From here northward the land scarcely attains the same elevation until the Paleozoic mountains of Arkansas are reached. Moreover, the Red and Ouachita rivers have degraded broad areas along their respective courses, reducing the general level of this higher portion of the state to perhaps less than 200 ft. A. T. In general, the state and the territory adjoining it on all sides is low, and comparatively speaking, of low relief. It may be interesting to note that as nearly as we can calculate from present data there are in Louisiana:

	Sq. miles.
Above the 400 ft. contour	375
" " 300 " "	2360
" " 200 " "	9240
" " 100 " "	17500
" " 50 " "	27250
" " 0 " "	45000

GEOLOGIC FORMATIONS AND THEIR WATER SUPPLIES

PRE-LAFAYETTE

CRETACEOUS

Stratigraphy.—A glance at the sectioned model, Plate II, will suffice to show the way in which the Cretaceous beds lie in northern Louisiana. In some places the folds or peaks actually come to the surface. But they are, as may be inferred from statements made above, but little lower than the Cretaceous outcrops in southwest central Arkansas. Moreover, they have suffered considerable folding and dislocation, facts which also tend to diminish the probability of any general artesian flow from these rocks.

Well at Drake's salt works.—It will be seen from Special Report No. II, pp. 57, 60, that the famous old well at Drake's salt works is still flowing, though feebly. About 111 ft. is the height of its mouth above tide, though, as will be seen by consulting the reference, it has flowed to a height of 150 A. T. The depth of the well has been variously estimated from 1010 to 1100 ft. It seems to have passes through soft limestone the whole distance. The Cretaceous age of those beds has been satisfactorily established. This we believe must be the well referred to by Darton * as at "Winnfield," La. for he gives 1100 ft. as its depth, 8 in. as the size, temperature as 70° ; and with gas. Veatch, however, gives size as 10 in ; temperature 75°.

Well at King's salt works.—This, according to Veatch is 136 ft. deep. The water rises to within 2 ft. of the surface and stands about 161 ft. A. T. See Special Report No. II, p. 77.

LIGNITIC EOCENE

Stratigraphy.—This formation crops out mainly north of a line drawn from Natchitoches to Sabinetown, and between the Red and Sabine rivers. Yet we suspect it is not far beneath the surface in that portion of the state west of Monroe and north of

* Water Supply and Irrigation Papers. U. S. G. S. No. 57, 1902, p. 50.

the V. S. & P. R. R., see Plate II, where the heavy black bars on white background indicate in a general way the position of the Lignitic beds.

Shreveport Ice Factory well.—This well as described in our former report (1899) reaches a water-bearing stratum 10 ft. thick at a depth of 961 ft. The level to which the water rises cannot be far from 190 ft. A. T. The proximity of the Cretaceous rocks is seemingly indicated by the saltiness of the water. We are somewhat surprised at the temperature recorded, *i. e.* 83°, being nearly 10° above the temperature given for Drake's well. Considerable quantities of gas come up with the water, loc. cit. p. 200.

Minden.—We have never visited the locality of the deep well at Minden. Darton, in his paper already referred to, gives as its depth 1000 ft.; and remarks, "No flow." We have thus far been unable to obtain more precise information concerning it.

Aldenbridge, Allentown.—Wells 400 ft. deep. Darton.

Benton, Bolinger.—Well 500 ft. deep. Darton.

Ruston.—This well although located in a Cocksfield or Lower Claiborne area, presumably draws its supply of water from the upper arenaceous beds of the Lignitic. The mouth of the well is not far from 300 ft. A. T. The pipe is 8 ins. for the first 200 ft.; 6 in. for the lower 250 ft., making a total depth of 450 ft. The pumps are so connected that it is impracticable to state how the water level stands, but we understood from the engineer of the water-works that it was perhaps but 200 A. T. It is evidently fine water, and is obtained at the rate of 100,000 gal. per day.

Dubach's well.—This is a small well at the engine house of the Dubach Lumber Co. Depth 296 ft. This formerly flowed 4 or 5 ft. above the surface of the ground, though it does so no more. Seemingly of good quality and when pumped furnishes all the water required by the Company. The well is about on a level with the R. R. station. Thus far, however, we have failed to obtain exact levels along the R. R. passing through this place.

Natchitoches Normal School.—The mouth of this well is approximately 130 ft. A. T. According to Pres. Caldwell, its section down to 504 ft. is as follows:

"The first 34 ft. penetrated, consisted of red and chocolate clays without sand or grit; next 18 in. of soft sandstone, iron-stained; moderate flow of water at 38 ft. very salt, derived from bed of grey sand, and rising over night to within 14 in. of surface; alternate beds of blue-grey and red-grey sandstone, and blue clay with occasional bits of pyrites and brown lignite, down to 96 ft.; at this depth a bed of very fine, nearly pure white sand, about 12 ft. thick, from which there was a strong flow of water not distinctly salt (the upper stream had been cased off); then chocolate clay, blue clay and thin bed of sand to 134 ft. At this depth, a solid bed of iron pyrites 10 ft. 8 in. thick, that took over three weeks to get through and wore out every style and make of drill in stock; then 12 ft. of very coarse rounded sand, nearly white; then 4 ft. more of pyrites; then alternate clay and sand, with one or two thin beds of slaty lignite, down to 462 ft. where there was a bed of shells and gravel and a 14-in. bed of lignite; then one unvarying bed of blue clay to the point where the work was abandoned, 504 ft."

Below 476 ft., the foreman of the Andrews Well Company, who sunk the well, gives the following log:

		Feet
Greenish, brittle clay with shells	to	547
Lignite	to	558
Clay with shells	to	678
Bowlder	to	681
Clay (no shells), rock, fine sand	to	728

The Times-Democrat in referring to this well says, (Feb. 17, 1900):—"After several months of disheartening trials, the artesian well at the Normal school has been finished. A good stream of water was struck at depth of 726 ft., but it is very salty, and perhaps can only be utilized for bathing and fire purposes."

The upper beds of the Lignitic here encountered at a depth of not greater than 200 ft. would furnish a fair supply of water. Good springs from this same geological horizon are common to the north of the village in the hilly region. A detailed discussion of this area can be found in our Report of 1899, p. 141, *et seq.*

Colfax.—The information we have regarding the well at this

locality is rather indefinite, but still, it suffices to show where, stratigraphically, the water is located.

Mr. Cameron furnished us the following section :

		Feet
1.	Soil, sand, gravel, clay with shells . . to	150
2.	Gypsum, with small spiral shells	
3.	Gas ; no water . . . at	660
4.	Salt water and gas . . . at	1100

"Water carries 20 grains of salt per gallon. Water and gas have been flowing for the past two years."

Darton gives the following data regarding this well :

Depth	1103 ft.
Diameter	2½ in.
Flow	42 gal.
Height of water	65 ft.
Temperature 62°	

The local upheavals in this vicinity (Rept. 1899, p. 61) doubtless are responsible for the seeming thinness of the Cocksfield, Jackson and Lower Claiborne beds. It is more than likely that the water is coming from a Lignitic horizon similar to that from which water is obtained in the deep well at the Natchitoches Normal school.

Monroe.—Although there seems to be a considerable development of Cocksfield beds along the V. S. & P. R. R. from Monroe to Ruston, and although the fossiliferous beds penetrated in the Monroe wells a hundred feet or more below the surface yield Lower Claiborne species, I am of the opinion that the supply of water at the Ice Works comes from the upper beds of the Lignitic. The wells hereabout are sunk 400+ ft. deep, and find an abundant water supply. When piped up it is said to rise 40 ft. above the level of the ground, *i. e.* 110 ft. A. T. (for the level of the ground here is 72 ± ft.) North of Monroe, from ½ to 1½ mile there are three similar wells. One in the garden of Mr. T. M. Parker has attached a vertical pipe about 20 ft. in height. The water, when stopped from leaking below would readily overflow at the top of this pipe, showing a head of at least 100 ft. A. T.

The town has had elaborate analyses made of the artesian waters obtained from the water-works wells, in the eastern part of the town, but they were mislaid and inaccessible at the time

of our visit to the place. It is said the water possessed various bad ingredients that rendered it unfit for general household uses. This is not strange when we consider the proximity of this region to the axis of the Embayment described at length in Special Report No. 1, a region during Eocene times replete with marsh-vegetation.

General conclusion.—We see no prospect for large flowing wells from the Lignitic area of the state. The water obtained by boring in these beds will be found of poor quality for the most part west of Red river, where marine shells occur imbedded in the sands and clays. These are the lower Lignitic beds. Higher up, near the Lignitic-Lower Claiborne contact, sands bearing pure water are often found; springs are also quite numerous at the base of local elevations. The Lower Claiborne being comparatively thin over the area so designated on the map, there are frequently good prospects of pumping if not flowing wells in the less elevated areas covered by the Lower Claiborne deposits.

LOWER CLAIBORNE EOCENE

We do not see how any considerable quantity of artesian or deep well water can be obtained from these beds. Nearly everywhere they contain a large amount of organic matter and the waters issuing from them are generally impotable. Where deep well water is sought in the Lower Claiborne districts, an attempt should be made to penetrate below into the upper Lignitic beds.

COCKSFIELD EOCENE

Alexandria.—Very satisfactory results have been obtained at this locality so far as quantity and quality of deep well water is concerned. A section of the water-works well sunk in 1892 furnished us, at the place, in 1901 is as follows:

			Feet
1.	Soil, then yellowish clay	to	200
2.	Green clays (evidently Grand Gulf)	to	270
3.	Black, brittle clay (Jackson)	to	527
4.	Rock	to	532½
5.	Clay (Cockfield)	to	541
6.	Water bearing sand 8 ft. thick, pure crystalline.		

This well is said to have been started with a 6-in. pipe and finished with a 2½-in. The surface of the ground is about 77

ft. A. T. Water level is reported as 12 ft. higher, or 89 A. T.

A third well put down in 1894 to a depth of 815 ft. is said to contain a 10-in. casing down to 210 ft.; an 8-in. to 612 ft.; 4-in. to 815 ft. Runs perhaps 70 gal. per minute and can be pumped to the extent of 500 gal. per minute.

Darton in his paper already referred to gives the following regarding these wells:

Depth	Size	Gals.	Height	Temperature
735 ft.	10-in.–6-in.	276½	+4	
850 ft.				
630 ft.				4 wells 85° ±

General remarks.—We know of no other place in the state where these beds are properly located and drilled into, so that general conclusions, regarding this water-bearing horizon can scarcely be drawn at present. Yet the probabilities are that the larger part of the Jackson area, where not over 150 ft. A. T., can profitably draw from the Cocksfield beds below to good advantage for their supplies of pure water. Flowing wells cannot be hoped for, however, except in regions less than 80 ft. A. T. The fact that the Colfax well did not produce water at this horizon is probably due to the local disturbances that brought up the Cretaceous beds across the river as described by Johnson. (See p. 61, Rept. 1899.) Again, Colfax is about 22 ft. higher than Alexandria and hence probably the same water if encountered would not rise to the surface; and it may have been overlooked entirely.

JACKSON EOCENE

So far as we are aware, these beds contain no desirable underground waters. Those who live on the Jackson outcrops cannot depend on finding good water at shallow depths. In case they are south of the Cocksfield-Jackson division line, (see Plate I of this report, or Geological map of Rept. 1899), and are not over 150 ft. A. T., there is hope for a good supply of deep well water at a depth less than 800 ft.

GRAND GULF OLIGOCENE

Springs.—The alternating layers of pure sands and impervious clay beds have much to do with the phenominally large number of

pure springs that issue in the Grand Gulf hills of Louisiana. The distribution of these springs is co-extensive with the outcrops of the formation. See the maps just referred to above.

Catahoula Shoals.—We have already referred to this locality in our Special Report No. 1. The section given by the U. S. Engineers as the record of the test well put down at this place is as follows:

Boring No. 4, Catahoula Shoals, La.

(77.0 miles above mouth of Black river. Elevation of channel 7.88 M.C.D.)

3-in. pipe. Flow 60 gals. per minute, 11 ft. A. T.

Feet A.T.	
11.06	Sandy mud
10.07	Sandy, clay and gravel.
7.78	Gravel.
-4.69	Grey sand.
-19.29	Blue-brown, sandy clay.
-41.44	Blue-grey rock.
-43.27	Very hard blue-grey clay or soft rock.
-65.12	Soft blue-grey rock.
-75.26	Blue sandy clay.
-128.61	Grey rock.
-128.94	Blue sandy clay.
-147.01	Fine grey sand. From this sand water flowed, 60 gal. per minute.
-186.45	Fine grey sand. From this sand water flowed, 60 gal. per minute.

General remarks.—This we believe is the only instance in Louisiana where the lower Grand Gulf beds have been tested with regard to their water-bearing properties. Across the Mississippi, however, the successful wells in Port Gibson are probably deriving their water from this horizon. We would expect that the "oil well" being sunk on Sicily island would encounter this water-bearing horizon at a depth of perhaps 300 ft. though it doubtless would scarcely overflow and make a true artesian well in that locality. From Harrisonburg, southwest, along the northern shore of Catahoula lake and even to Alexandria, water should be found in this stratum at a depth scarcely over 300 ft. It would probably not flow above the surface of the ground, unless in exceptionally low places.

LAFAYETTE AND MORE RECENT DEPOSITS

AMOUNT AND OCCURRENCE OF WATERS

Importance to Southern Louisiana.—The amount of water derived from other formations in Louisiana is extremely insignificant when compared to the yield of these beds. In our introductory remarks to this Special Report, we took this horizon as showing most clearly the occurrence of under-ground waters in Louisiana. From the phenomena of precipitation in the region of Lafayette outcrops, in the central portion of the state, to the out-flowing of copious streams from deep-drilled holes not far from the Gulf border, there is nothing unnatural, or peculiar to be observed. The water is at all times simply seeking its lowest level in accordance with the law of gravity.

Pressure head above tide.—We have shown in our opening statements how the water exists beneath a bed of Port Hudson clay in a state of hydrostatic pressure, how the upper surface slopes from 60 or more ft. above tide in the higher planes in the north, to perhaps 6 ft. above tide along the Gulf coast. It might have been mentioned there, too, that there is a considerable irregularity in the upper surface of this underlying water in an east-west direction. Because water in one well stands say at 15 A. T. it is no sure sign that it will stand at exactly the same level in a well from 500 yards to a mile away in any direction of the compass. Doubtless if the water were under simple static pressure, in course of time it would assume in the various wells the same level, but give this water even a slight flow, from leakage Gulfwards or from vigorous pumping over large areas to the south, and then the different resistance the different portions of the waters meet in their passage southward through beds of sand and gravel of various dimensions and states of consolidation, shows clearly in the varying height to which water will rise in different wells. Attention should be called to the fact that there is not, beneath the Port Hudson beds in southern Louisiana, the homogeneity of structure that is usually represented in sections of this region. The driller knows well that the outlying clays are from 60 to 150 ft. in

thickness, sometimes solid, sometimes with sand-beds at various horizons and of varying thickness. The water-bearing beds were, until 1902, usually spoken of as blue sands, owing to the fact, doubtless, that only the fine material is brought to the surface by the rotary process of sinking these wells so much in vogue in southern Louisiana. It is now recognized that the best producing wells have their strainers in coarse gravel. This, owing to the lack of continuity of any of these beds, leads to the sinking of wells in localities, often in close proximity, to quite different depths.

Some general statements, however, can be made regarding the height to which these underground waters may be expected to rise, when once they have been met with in the coarse, gravelly material. So far as the Lake Arthur-Smithville section is concerned (see Fig. 21), little more need here be said—but attention should be called to the fact that, although the prairie region of St. Landry parish is somewhat more elevated than the lands on the same latitude to the west, there is not a corresponding rise in the hydraulic surface that might at first thought be expected. For example, at Opelousas, although the data relating to this point are not as definite as we would like, the surface of the deep well waters seems to be but about 25 ft. A. T. While due west between Kinder and Oberlin the surface is about 45 ft. A. T. At Lafayette and Rayne the surface of the deep well water is about 23 ft. A. T.; at Webster and Lake Charles it is 25.

On the opposite side of the Mississippi at Pearl river the surface of underground water, in wells from 300 to 600 ft. deep, rises to 54 ft. A. T.; at Covington, 40 ft.; at Baton Rouge about 30–35 ft. In general, then, it may be said that there is a tendency for the subterranean waters along the same line of latitude to descend somewhat in approaching the Embayment axis, or to rise in the opposite direction.

On the east side of the Mississippi there is of course the same rise of the surface of subterranean waters to the north that we have described along the Lake Arthur-Smithville section. For example, water in the wells at Covington stands at an average height of about 40 ft. A. T., but 2 miles north on the Hernandez place, the height is no less than 60 ft. At Baton Rouge the

surface in question is scarcely over 35 ft.; at Baker it is over 90 ft. A. T.

The general conclusion to be drawn from the foregoing discussion, regarding the upper surface of the Lafayette water, is then the following : Towards the south and towards the Embayment axis there is a marked decline in the subterranean water surface and there is a much more rapid slope Gulfward east of the Mississippi than there is to the west.

Two important water-bearing horizons.—East of the Mississippi two or more fairly distinct water-bearing horizons are found. The first and lowest is reached at depths ranging from 400 to 700 ft. according to position and local topography. This includes wells at Scranton, Mississippi City, Biloxi, Ship island, Bay St. Louis, Pearl river, Mandeville Junction, Covington, Hammond, New Orleans, Lake City, Baton Rouge and Baker. The second is reached at depths ranging from 150to 700 ft. according to local surface features as well as geographic position, and includes such wells as those about Lake Catherine, Mandeville and Manchac.

There is still a third of less importance and lowest of all, that is met with in 1200 to 1400 ft. wells in the City of New Orleans. This has been correlated with the Ship island-Covington horizon, but the character of the water and the force with which it flows indicate in our mind a deeper source and higher head than the Covington wells possess. The Bonnabel well (Lake City well) 900 ft. deep is quite probably of the same horizon as the 600–700 ft. wells in New Orleans. That Lakes Maurepas and Pontchartrain lie in a shallow synclinal trough we have had occasion to note on several occasions.

On the west side of the Mississippi alluvium, nearly all subterranean water is being obtained from the upper of these two horizons. It is this horizon alone that we have used in the general deductions stated above.

We are not aware that wells have yet been sunk, in search for water, to a sufficient depth, say along the Southern Pacific territory, to reach the lower lying horizon. At the Crowley Ice factory one was put down to the depth of 600 ft., but this can scarcely be regarded as deep enough to penetrate the lower stratum. The well was not reported as a success. In fact it was

said that the casing was withdrawn and the screen placed at the usual depth of about 180 ft.

It must not be understood that we believe there are, in all of southern Louisiana, two very distinct or sharply defined water-bearing horizons. As we have remarked before, there is not the regularity of structure in these late Tertiary or early Quaternary beds that one would suppose from a study of the usual geological sections of the region. In some districts sands prevail at the same depths that finer material, even clay, occurs in wells close by. The above statements are, however, in a general way true.

In the vicinity of Lake Charles there is not the usual supply from the 200 ft. horizon, but water-bearing sands are found at about 500 ft.

DETAILS OF PLANS OF INVESTIGATION AND RESULTS

Bench marks—Elevations.—In continuing our work on the underground waters of this state we secured at the outset as much information as possible regarding elevations of stations along the railroads and bench marks of the U. S. Survey along the principal rivers. By means of these bench marks, or points of known elevation, the relative heights of the water as it appears in nearby wells can readily be determined. This is, naturally, by the use of some kind of a spirit level with an accompanying rod. We ran in all over 100 miles of such lines for this special purpose. Extreme accuracy in such work is, of course, quite out of the question; for nothing is to be gained by attempting "precise" leveling from points whose actual height is perhaps not known to the nearest foot, as for example the height of the various railroad stations. Again the daily variation of the water in the wells is in some instances considerable. For our work we found a light, small, dumpy level precisely the thing. Its construction is such that it rarely gets out of adjustment. It is so light that it is not a load in itself. This we find an important item, for the geologist if alone or with but one attendant is always loaded with his necessary pariphinalia. The character of work that can be done rapidly with this instrument is such as to recommend it for all common and reconnaissance work. After an experience of over 2 years with this instrument, we can

state that a mile can be run twice within .10 ft. to .01 ft. of the same without fail. This we know from many miles of duplicate and tie lines. The general form of our instrument is shown by

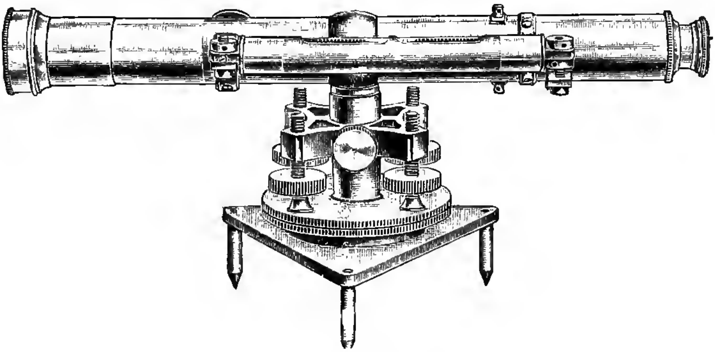


FIG. 23.—DUMPY LEVEL.

Fig. 23, though of course the ordinary tripod was substituted in place of the metal trivet.*

WELL SECTIONS EAST OF THE MISSISSIPPI

Introductory remarks.—It is entirely out of the question to attempt to enumerate but a few among the many deep wells that have been put down in the southern part of Louisiana. As a rule the records kept are scanty in the extreme; the object sought is water and little attention is paid to what the formations are, which are encountered before water is reached. In some instances, however, a few fossils have been saved by neighboring inhabitants and in others, the materials thrown out can be examined, at leisure if the well is of recent date. Exact data relating to depth, however, can scarcely be obtained in this way.

Our personal investigations have extended from Mobile, Alabama to Sour Lake, Texas, though in the territory outside of Louisiana, a comparatively small amount of time has been spent.

* As we mentioned in case of the Railroad compass, various firms sell instruments of this general grade and character. Ours, however, the one figured, is catalogued by Keuffel and Esser, (127 Fulton St., New York City), for $35.00 including tripod, box, adjusting pins, etc. complete.

Ship Island, Quarantine Station well.—Depth, 730 ft.

Section by Dr. P. C. Kallock :

Soil		Feet
White Sand	to	45
Soft clay and mud	to	200
Hard blue clay	to	300
White sand	to	305
Blue clay	to	565
Sandstone	to	565½
Blue clay	to	721½
Water-bearing sand	to	730

Elevation : mouth of well perhaps 10 ft. A. T.

Ship Island Light House well.—Depth, 750 ft.

Section by Dr. Murdock :

	Feet
Sand	250
Yellow clay	350
Blackish mud	400
Fine sand with shells	450
Blue clay	700
Water-bearing sand	750

Elevation : mouth of well perhaps 10 ft. A.T.; flows vigorously at that height.

Mississippi City, C. Clemenshaw's well.—Depth, 925 ft.

Statement of Mr. Clemenshaw :

"Passed through no hard rock, no quicksand, but clay and blue sand, the latter often highly micaceous. A 60-gal. flow was obtained at 600 ft.; at 925, a 200-gal. per minute flow was obtained."

Elevation : mouth of well about 18 ft. A. T.

Mississippi City, C. P. Ellis' well.—Depth, 850 ft.; 3-in. pipe; flows 80 gal. per minute.

Elevation : top of well, 55 ft. A. T.

Mississippi City, Court House well.—2½-in. pipe, reduced to 1½-in. Runs 20 gal. per minute, 28 ft. above the surface of the ground.

Elevation : top of well perhaps 50 ft. A. T.

Pass Christian to Ocean City, general section.

Section as given by Archie Dixon, driller of Pass Christian :

		Feet
Sand	to	80
Clay	to	125
Sand and clay	to	425
Light grey fine sand	to	500
Clay	to	600
Water-bearing sand	to	685

Bay St. Louis.—Darton, in Irrigation Papers, U. S. G. S. No. 57, gives the following data for the region : "Many wells. Temperature of deeper, 78°. Depth, 400–700 ft.; size 4½ –2 in.; yield per minute, 100–105 gal.; flowing."

Lake Catherine.—Artesian well observed. No further data.

New Orleans, Class A, deeper, 1200–1400.—Young Men's Gymnasium Building. Depth, 1356 ft.; natural flow, 40 gal. per minute, forced 125 ; gas escapes 830 cubic ft. in 24 hours ; specific gravity, 1.016.

	Pts. in 100,000	In a gal.
Chloride sodium	2115.9	2.82 oz.
Chloride calcium	138.2	81.2 gr.
Chloride magnesium	75.7	44.9 "
Chloride ammonia	1.3	.8 "
Chloride potash	trace	trace
Carbonate calcium	86.8	40.8 "
Oxides of Fe. and Al	4.7	2.8 "
Phosphate	trace	trace

Analysis by Ordway and Kirchoff.

A well of similar depth and saline character we understand has been sunk for the Southern Athletic Club.

Elevation : perhaps 15 ft. A. T.

New Orleans, Class B, shallower wells.—These include the 600–750 ft. wells bored at frequent intervals over the city. One of the earliest wells of this class sunk in New Orleans was in the Neutral Ground on Canal Street, between Carondelet and Baronne Streets, in the year 1854. A colored section of this well, as originally kept by A. G. Blanchard, C. E. of New Orleans, is inserted opposite p. 148 of the "Biennial Report of the Board of Health, to

the General Assembly of the State of Louisiana, 1890–91, Baton Rouge, 1892." From this it will be observed that the strata penetrated to a depth of 630 ft. consist of light yellowish and bluish sands and clay, with some light greenish layers and occasional shell sands.

One of the most recent wells of this class is that at the Marine Hospital, Audubon Park. This is 765 ft. deep. The first 600 ft. are reported as sand, silt and clay beds, a bed of yellowish sand perhaps 40 ft. thick was encountered some distance below and continued to 705 ft. From there on, for 60 ft., the material consists of white sand. The water rises to within about 3 ft. of the surface at present. This 6-in. well is capable of furnishing 300 gal. per minute. The water is classed as excellent for washing purposes, requiring but half the soap the river water does; it is also excellent for boiler use; impotable.

The flow from this shallower class of wells has always been weak; and the large number of such wells has still further weakened the flow. There is a tendency now, when more water is required, to seek the lower level, This is excellent for bathing purposes, containing as the above analysis shows, a large amount of common salt.

On p. 154 of the Report of the Board of Health, referred to above, will be found analyses of six so called "deep well waters" of New Orleans.

Lake City, Bonnabel well.—Depth stated by Bonnabel to be 1200 ft.; according to information given by the president of the Artesian Well Co., N. O., it is 900 ft. in depth. Said to have arisen 60 ft. above lake level; now flows out readily at 8 ft. A. T., though apparently with no great force; temperature according to Bonnabel, 78°.

Section as given by Mr. Bonnabel:

"Five-inch casing to 600 ft. deep, hitting rock; three-inch casing to 700 ft.; then one and one-half-inch casing to 1200 ft.

"Compact ferruginous conglomerate, 60 ft. thick passed through about 700 ft. down. Then a black, hard clay was encountered, giving way to bluish sand; water in pale bluish sand."

Analysis by Jos. Albrecht:

	In 1 gal.
Chloride of sodium	27.74 gr.
Sodium carbonate	34.39 "
Potassium carbonate	4.49 "
Silica carbonate	1.69 "
Organic matter free of nitrogen	0.46 "
Carbonic acid combined as bi-carbonate	13.33 "
Total	82.10 gr.

Mandeville,* *Dessome's well at flower garden.*—Depth, 217 ft.; pipe, 2-in.; flow, 28.1 gal. per minute, March, 1901; 26 gal. per minute, March, 1902; temperature, 69½°. For analyses given below.

Elevation: of pipe, 9 ft. A. T.; pressure head, 14½ ft. A. T.

Mandeville, Dessome's well at residence.—Depth, 220 ft.; pipe with 1-in stop cock; temperature, 71°.

Mandeville, Mrs. Jno. Hawkins' well.—Pipe, 2-in. reduced to 1¼; flow, 40 gal. per minute, 1902; temperature, 68½°.

Elevation: of flow, 7.35 ft. A. T.

Mandeville, C. H. Jackson's well.—Depth, 136 ft.; 1.5 in. reduced to 1 in.; flow, .97 gal. per minute.

Elevation: of flow, 13.8 ft. A. T.

Mandeville, Dr. Paine's well.—Flow, open 2-in. pipe; 10⅔ gal. per minute; with reduction to 1 in.; 10½ gal. per minute; with inch pipe and stop-cock attached, 9.10 gal. per minute.

Mandeville, Ribava's well.—Depth, 247 ft.; flow from 1¼-in. pipe, 12 gal. per minute, 1901; with stop-cock in place and open 9.2 gal. per minute; temperature, 71°, February, 1902. Elevation: of ground 3.42, flow, 4.90 ft. A. T.

Mandeville, shallow wells.—Several, 90 ft. deep; flow about 4 ft. A. T.

Mandeville Junction, R. R. well.—Depth, 598 ft.; flows freely 27 ft. above ground. Exact height A. T. not determined.

* We did not have time to watch a tide gauge over a period of more than two days, hence all these heights are subject to a slight modification. According to our "°" mark, the top of the rail before the station is 6.80 ft. A. T.

Chinchuba Deaf Institute.—Depth, 325 ft.; pipe 2-in.; flow, reduce to a 1/3-in. pipe and hence with low pressure, very small; pressure head 7 1/3 ft.; temperature 72.°

Elevation: of ground, 19 ft., A. T.; pressure head, 28 ft. A.T.; a well 4 miles to the northwest of here, 800 ft. deep is said to have a similar pressure.

Pearl River Junction, well at hotel.—Depth, 350 ft.; pipe 2 1/2-in.; flow through reduced pipe, and one-half in. stop-cock 72 gal. per minute; said to flow 90 gal. per minute from 2 1/2-in pipe.

Elevation: station 31 ft. A. T.; pressure head 54 ft. A. T.

Covington, Maison Blanche well.—Flow from 2-in. pipe reduced to 1 in. April, 1901, 20.4 gal. per minute; March, 1902, 23 1/2 gal. per minute; temperature 72 1/4°.

Elevation: ground, 31.5 ft.; top of basin, 33.6 ft. A. T.; flow about 35 1/2 ft. A. T.

N. B. These elevations about Covington are all referred to the top of the rails in front of the R. R. station. This we have called 32.5 ft. A. T. from our series of levels running from L. Pontchartrain to Covington along the highway.

Covington, Dummet's well.—On Holmesville road, record by Robert Wallbillick. Flow 21 gal. per minute; 2 ft. above the ground.

	Thickness, ft.	Depth, ft.
White clay	15	15
Yellow clay	6	21
White clay	35	56
Coarse white sand	25	81
Fine gravel	12	93
Coarse white sand	6	99
Coarse white sand and gravel	14	113
Coarse yellow sand and gravel	6	119
Coarse yellow sand	8	127
Gravel	10	137
Red clay	1	138
Gravel	10	148
Red clay	2	150
Gravel	10	160
Red sand and gravel	20	180

	Thickness, ft.	Depth, ft.
Gravel	32	212
Red sand	38	250
Coarse gravel	25	275
Coarse white sand	4	279
White clay	18	297
Blue clay	183	480
Water-bearing sand, bluish and greenish (fine)	7	487
Blue clay	71	558
Grey sand	6	564
Fine blue and greenish sand	8	572

Covington, Jno. Dutch's well.—Flow 20 gal. per minute; temperature 74°; on the 17th April, 1901.

Elevation: of ground, 32.7 ft. A. T.; of pipe, 35.6 ft. A. T.

Covington, Mrs. Flower's place, shallow wells.—Records by Mr. Wallbillick:

No. 1.

		Feet.
White clay	to	30 5
Blue clay	to	49
White sand	to	51
Blue clay	to	68
Shells mixed with blue clay	to	69.5
Fine white sand	to	97
Coarse white sand	to	103

(Pumping stratum.)

No, 2.

(300 ft. from No. 1.)

White clay	to	40
Blue clay	to	42
White clay	to	63
Shells mixed with black clay	to	63.6
Dark clay	to	73
White sand	to	94

Covington, Court House yard well.—Flow 2½ gal. per minute; temperature 73°; April, 1901.

Elevation: ground, 32 ft. A. T.; pipe, 35.6 ft. A. T.

Dixon Academy well.—Pipe 2½-in.; flow 25 gal. per minute.

Elevation: 26.7 ft. A. T.

Claiborne, 1 mile E. of Covington, Lyon's well.—Depth, 630 ft.; pipe 2-in.; flow 30 gal. per minute; temperature 73°; April, 1901.

Elevation: 26.6 ft. A. T.

Abita Springs, Simons hotel well.—Pipe 1½-in.; two elbows and one 2-ft. horizontal pipe with flow of 12 gal. per minute; flowed 11 gal. per minute in April, 1901; temperature at the same date 72°.

Elevation: of ground, 38.3 ft. A. T.; top of basin 41.7 ft. A. T.; top of pipe, 43.6 ft. A. T.

N. B. Top of rail at station is the local bench mark to which the levels at Abita Springs are referred. A line of levels run from Covington, gave us for this station 38.3 ft. A. T.

Abita Springs, Aubert's hotel well.—Depth, 585 ft.; pipe 1½-in.; flow 12.7 gal. per minute, January, 1901; original flow said to be 25 gal. per minute; variation probably due to friction in about 60 ft. of piping with five right angles. See Table of analyses given below.

Elevation: of ground, 35.8 ft. A.T.; faucet, 38.3 ft. A.T.; pressure head over 50 ft. A.T.; said to have been 78 ft. A.T. at first.

Abita Springs, Labat's hotel well.—Flow from faucet 37.1 gals. per minute. This is the best well that we observed in this vicinity. Its exact depth was not given, but it does not differ much from the ordinary 600 ft. wells of this vicinity.

Elevation: of ground, 41.5 ft. A.T.; of faucet, 45.2 ft. A.T.

Abita Springs, Schmid's well, by depot.—Flow from 1½-in. pipe, but through a ½-in. faucet, 4 gal. per minute.

Elevation: of ground, 35.6 ft. A.T.; of faucet, 36.6 ft. A.T.

Hernandez place, 2 miles N. of Covington, well by house.—Depth, 610 ft.; pipe 2½-in.; flow from 1-in. pipe January, 1901, 38.5 gal. per minute; appears to have great pressure. Flowed 60 gal. per minute in April, 1901; temperature at the same time 73°.

See Table of analyses, given below.

Elevation: of ground, 46.1 ft. A.T.; of top of basin, 47.3 ft. A.T.; of pipe, 48.5 ft. A.T.

Hernandez place, well by barn, 2½ miles N. of Covington.—Depth about the same as well just mentioned, pipe 2½-in.; flow as measured roughly in January, 1901, 35.3 gal. per minute; as measured more accurately in March, 1902, 54.3 gal. per minute.

Elevation: of ground, 47.4 ft. A.T.; of pipe, 52 ft. A.T.; pressure head considerably over 60 ft. A.T.

Fredrick and Singletry's still, well at.—Exact location is S. W. ¼, N. W. ¼. Sect. 31, 5 S. 10 E. Depth, 560 ft.; pipe about 2 in.; flow 18 gal. per minute, with several leaks; true flow probably considerably more.

Sections as given by Mr. E. P. Singletry:

	Feet
Sand and clay ....for	100
Quicksand ....for	120
Red clay.........for	170
Pipe clay.........for	160
Blue sand ....for	10

For analysis, see table given below.

Elevation: of ground, 75 ft. A. T.; of pipe, where water flow was measured, 78 ft. A.T.

Mammoth Springs near Franklinton.—We have not visited this locality but Mr. E. S. Ferguson of New Orleans says that the spring is about 268 ft. A.T. and flows out as a cool large branch.

Pontchatoula, Town well.—Depth, not obtained; flow, 2½ gal. per minute; temperature 71°.

For analysis, see table given below.

Elevation: of flow, 33± ft. A. T.

Pontchatoula, G. H. Beigel.—Depth, 232 ft.; flow 4¾ gal. per minute; temperature 71°.

For analysis, see table given below.

Elevation: of flow about 31 ft. A.T.

Hammond, Ice Factory well.—Depth, 340 ft.; pipe 2-in.; flow 15 gal. per minute at a height of about 50 ft. A.T.; temperature 72°.

Elevation: of Hammond given by Ill. Cent. Engineer office N.O., 43.3 ft. A.T.

N.B. no spirit leveling was done about Hammond and heights of flows were estimated from the lengths of pipe above the generally level surface.

Hammond, Merritt Miller's well.—Depth, 265 ft.; pipe 2 in.; reduced to 1¼-in.; flow 28¼ gal. per minute; temperature 71°.

Elevation: of flow about 44 ft. A.T.; pressure head about 56.6 ft. A. T.

Hammond Morrison well.—Pipe 2-in.; flow 20 gal. per minute.

Elevation: of flow, 46 ft. A. T.; pressure head about 51.7 ft. A. T.

Hammond, Durker well.—Depth, 297 ft.; flow 24 gal. per minute; pressure 4 lbs. per sq. in.; pipe 2-in. reduced to 1¼-in.

Elevation: of flow, about 44 ft. A. T.

Hammond, 1½ miles S. of Eastman's well.—Depth, 309 ft.; pipe 2-in.; flow 30 gal. per minute; pressure is 5.5 lbs. to sq. in. = 12.65 ft.; temperature 72°.

Hammond, 1½ miles S. of L. J. Way's well.—Depth, 140 ft.; 3 gal. per minute, temperature 69°.

Hammond, 2 miles S. S. W. of, Dr. Hermann's well.—Impossible to obtain accurate data except pressure; pressure 8.5 lbs. per sq. in. = 19.5 ft.

Hammond, 3 miles S. S. W. of, W. J. Wilmot's well.—Depth, 370± ft.; pipe 2-in. reduced to 1-in.; flow said to be 40 gal. per minute; pressure 2 ft. above ground is 7.7 lbs. per sq. in.; with some small leaks in pipes flows at 14 ft. above ground. Would doubtless flow about 20 ft. above ground.

Hammond, Oil well, samples examined Feb. 20, 1902.—

Section preserved in glass jars show:

	Feet.
Clays	45- 55
Sands and gravel	85-100
Yellow loam	173
Water-bearing sand	294
Coarse sand	368
Coarse sand and gravel	475
The same, more sandy	500-512
5 ft. bed of hard blue clay at about	570
"Pepper and salt" sands	570+

Hammond, Pushee's well.—Depth, 325 ft.; flow, March, 1901, through a 1½-in. pipe, 14½ gal. per minute; 1½-in. pipe, 15½ gal.; April, 1901, through a ¼-in. pipe, 4⅓ gal.; ½-in. pipe, 14½ gal.; 1½-in. pipe, 15½ gal.

Natalbany, ⅛ mile W. of Station, Natalbany Lumber Co. well.—Depth, unknown; pipe 1¼-in.; flow, 2 gal. per minute. This well, 3 miles north of Hammond, marks the northern limit of the proven artesian territory of this section.

Baton Rouge, Waterworks, 2 wells.—Old well put down in 1892; depth 758 ft.; water rises to within 6 ft. of surface, *i. e.* approximately 30 ft. A. T. Capacity estimated at 500,000 gal. daily; cost $4,000.

Analysis by B. B. Ross 1892 shows in one gallon:

	Grains.
Total solid matter	14.3175
Mineral matter	12.1597
Organic and volatile matter	2.1578
Silica	1.3413
Potash	.2251
Soda	5.9929
Lime	.5009
Magnesia	.2939
Oxides of Fe and Al	.5056
Phosphoric acid	.03196
Sulphuric acid	1.8819
Chlorine	.4655
Oxygen, oxidizing organic matter	.04228
Nitrogen, albuminoid ammonia	.00676
Nitrogen as free ammonia	.00519
Nitrogen as nitrates	.00192
Sulphuric acid and chlorine combined as:	
Potassium sulphate	.4171
Sodium sulphate	3.0022
Sodium chloride	.7494

This well has an 8-in. pipe for 386 ft.; 6-in. pipe for 304 ft.; 4½-inch pipe for 68 ft. New well starts with 10-in. pipe and is 6 in. the rest of the way down; flows at surface about 35 ± ft. A. T. The two wells are said to be capable of furnishing 1,000,000 gal. daily.

Baton Rouge, about 5 miles east of.—The comparative height of this well and the two at Baton Rouge cannot be now given

for want of an accurate spirit-level line connecting the two localities. It is surprising, however, in view of the low head at the Baton Rouge wells, to see this one flowing from an inch pipe with so much vigor.

Baker, ¼ mile S. of station, well at old mill.—Depth, 850 ft.; 2-in. pipe; has flowed freely 16 ft. above present faucet. It furnishes now, large quantities of water.

Elevation: pressure head, about 100 ft. A. T. (Baker station given by Gannett as 82 ft. A. T.)

Baker.—Driven wells, 150 ft. deep, furnish fair water.

Baker.—Bored wells, 25 to 40 ft., deep yield very impure water.

Zachary.—Wells here, some as deep as 200 ft., have to be pumped. Most of the water used is from shallow bored wells.

Bayou Sara.—Well just S. E. of R. R. station, 240 ft. deep; passed through gravel at 100 ft.. It is pumped. Darton gives the following data from one well at this place: Depth, 736 ft.; pipe 4-in.; yield 347 gal.; height of water [above mouth of well?] +2 ft.; temperature 63°. For another he gives simply depth 450 ft. and "height" +1 ft.

WELLS WEST OF THE MISSISSIPPI

Thibodaux, Ice Factory well.—Depth, 227 ft.; passed through moderately fine bluish sand all the way down; water impotable on account of various salts; stands 13 ft. below the surface; used for condensing.

Glencoe.—Clendenin gives a section of an *artesian well* at this place furnished by Dr. Simmons. It reaches coarse sand and gravel and water at 612 ft.

Morgan City, station east of.—Said to have passed through very coarse gravel, heavy bed, at 500 ft.

Marksville.—Darton gives a well at this place a depth of 800 ft. with no further comment.

Delta.—Darton mentions a 1200 ft. well at this place, with "no water."

Bastrop.—

Elevation: Bench mark on pine tree about one-fourth mile north of the R. R. station reads 114.60 ft. C. D. With this as a starting point, levels were run to Campbell House well, ∴ top of curbing 132.8 C. D.; depth to water 66.5 ft.; hence height of water, 66.3 ft. C. D. = about 45.4 ft. A. T.

Height of planking over Court House well, 133.66 C. D.; depth to water 67.1 ft.; hence, 66.56 = height of water C. D. or 45.62 ft. = height of water in C. H. well above tide.

Lake Providence well No. 3.—The most interesting well section of this region is the one described by E. W. Hilgard in House Executive Documents, 1st session 48th Congress, vol. 19, 1883, page 494. No mention, however, is made of encountering water-bearing strata:

Alluvium:	
Non-calcareous clayey silt with abundant vegetable matter, not lignitized	0–56
Port Hudson:	
Coarse sand with gravel and grains of lignite. A clay streak occurs at 82.5–82.6	56–109
Upper Claiborne (Tertiary):	
Whitish greensand marl. On washing and settling the greensand falls to the bottom, the red sand occupies the middle and the calcareous debris lies on top.	127–132
Green sand marl like the last with calcareous concretions containing shell fragments	132–135
Concretions from marl bed with shell fragments	145–150
Bluish clay with lignite grains	158–160
Fine sand of a clay color, with greensand	166–176
Bluish clayey silt with lignite grains	176–181

From what has already been said in the early part of this report, it is quite safe to say that water might be found in the Cocksfield beds below the Jackson (which Hilgard has called "Upper Claiborne") at a depth of perhaps not over 1000 ft. The grave question is as to the character of such water in the very midst of the old Mississippi Embayment.

Lake Providence.—Well sunk March–April, 1901; log kept by

Mr. Jno. L. Kennedy; depth, 112 ft.; water rises to within about 15 ft. of the surface, though shows fluctuations with river; section 93 ft. is as follows:

	Feet
Black, blue, red loam	10
Fine sand	19
Coarse, water-bearing sand	34
"Concrete"	38
Water-bearing sand	77
"Concrete"	79
Sand	85
"Concrete"	86
Water sand	93

"Abandoned at 112 ft.; the water being found most too ferruginous for all-round purposes."

Jeanerette, Moresi's barnyard well.—Depth, 140 ft.; pipe, 1½-in.; flow, Feb. 16, 1901, 7½ gal. per minute; temperature, 70°. See Table of Analyses given below (page 251.)

Elevation: of station 18 ft. A. T.; well 13.2 below station, hence, flow is about 5 ft. A. T.

Jeanerette, Moresi's foundry well.—Depth, 700 ft.

Section given as follows:

		Feet
Clay	to	40
Sand and gravel	to	200
Blue and gray clay shells and red water	to	660
Gravel	to	700

See Table of Analyses given below (page 251.)

Elevation: 5.5 ft. below R. R. station; water stands within 5 or 6 ft. of the surface; hence, water is about 8 ft. A. T.

Jeanerette, Ice Factory well.—Pipe 8-in. Clendenin gives this well section as follows:

		Feet
Red clay	to	15
Mottled clay and sand	to	95
Organic bed	to	105
Sand and gravel	to	175
Yellow clay	to	350

Elevation: flow from base of cap, 7.69 ft. below railroad station or about 10.5 ft. A. T.

Jeanerette, 3 miles S. of, Kilgore plantation.—Section as follows :

		Feet.
Clay	to	80
Gravel	to	86
Clay, full of shells	to	236

New Iberia, Ice-works wells.—We had no opportunity of finding out the exact size and depth of these wells. They flow, at first, at a height of 8.4 ft. below the R. R. station or about 13 ft. A. T., but the water is rather chalybeate and soon clogs up the pipes.

Darton gives as depth of a New Iberia well, 600 ft. New wells have been put in at the water-works, but those cognizant with facts of drilling were not present at the time of our visit.

Lafayette water-works wells.—We have here an instance of lack of care in leaving the wells accessible for cleaning. The first gave out because it became clogged, probably with sand. Hence a second well was drilled very close to the first and it proved a success. We were told that the new well was 240 ft. in depth and had an 8-in casing.

Elevation : of station, 48 ft.; of water in well, 27 ft. ± A. T.

Lafayette Compress and Storage Co's well.—Depth, 125 ft.; water surface, 25 ft. below surface of ground.

Opelousas.—Several wells ; depth about 135 ft.; gravel struck at about 90 ft.; water rises to within 35 or 40 ft. of surface, *i. e.* 10 ± ft. A. T.

Washington.—Section given :

		Feet.
Quicksand	to	18
Sand	to	70
Gravel	to	194

Elevation : water rises to within 11 ft. of surface or about 30 ± ft. A. T.

Abbeville Court House well.—Well about 16½ ft. A. T. with section :

		Feet.
Clay	to	15
Fine sand	to	80
Clay	to	82
Hard layers of clay alternating with sand	to	139
Coarse white sand with white pebbles	to	160
Reddish clay and "rock"	to	220

The upper bed here alone furnishes water; exact height of the latter could not be told, certainly it lacks several feet of overflowing.

Abbeville, 9 miles west of.—On Mr. Jno. Waltham's place W. ½, S. E. ¼, Sect. 32, 12 S., 3 E., are several wells. The land is here about 10 ft. A. T., and the general well section according to Mr. Moresi is about as follows :

		Feet.
Clay	to	30
Gray sand	to	40
Clay	to	45
White sharp sand and gravel	to	75 and deeper

Even at this low level the water does not overflow.

Rayne, Chapius' well.—Depth, 210 ft. with 10-ft. strainer ; water stands 16 ft. below surface.

Elevation : of station, according to Gannett, 41 ft. A. T., well about 2 ft. below, hence, water in well about 23 ft. A. T.

Rayne, Hippolite Richard's well.—This is 3 miles E. N. E. of Rayne. Depth, 200 ft.; water stands within 17.5 ft. of surface.

Elevation : of surface of water in well about 22.5 ft. A. T., based on spirit-level line run from Rayne to mouth of well.

Crowley, Railroad well.—Depth, 173 ft. Water usually rises to within 5 or 6 ft. of surface.

Elevation : of water, about 24 ft. A. T.

Crowley, Ice Factory well.—Depth, 600 ; unsatisfactory ; pipe withdrawn to the usual 170–180 ft. depth.

Crowley, 15 miles N. E. of, at Long Point.—One 8-in. and three 6-in. wells. Water at 180 ft.; rises to within 26 ft. of the surface.

Crowley, 3 miles E. of.—Two wells pass through logs at depth of 168 and 202 ft. respectively. In the first, beneath the 168 ft. log, 7 ft. of water-bearing sand was encountered; water rising to within 7 ft. of surface.

Gueydan, 3 miles S. W. of, Wilkinson's well.—Depth, 190 ft.; pipe, 8-in.; flow, 8 + gal. per minute; temperature, 73°.
Elevation: of flow, 6.9 ft. A. T. Determine by spirit-level line from Gueydan; B. M. on station, according to Southern Pacific R. R., 9.07 ft. A. T.

Gueydan, 6 or 7 miles E. of, Donnelly place.—Two 8-in. and two 6-in. wells. Water said to rise 8 in. above the surface.

Oriza, 1 mile S. W. of, Jno. Wendling's well.—Pipe, 6-in; flow, 1.2 ft. above surface; 20 gal. per minute.
Elevation: of Oriza (S. P. R. R.) 24 ft. A. T. By spirit-level line, top of well is 11.4 ft. A. T.

Oriza, 2 miles S. W. of, D. J. Scanlin's well.—
Elevation: surface of water, 12.2 ft. A. T.; line from Oriza.

Oriza, 2 miles S. S. W. of, F. Scanlin's well.—
Elevation: surface of water, 12 ft. A. T., leveled from Oriza.

Jennings.—The number of deep wells about Jennings is very large. It is entirely out of the question to enumerate even one-tenth of them here.

Mr. Carey gave us the following statement regarding his first three wells:

0–115 ft.—Clay, with shells at about 50 ft., with vegetable matter, logs below.
115–160 ft.—Quicksand above, gravelly below.
160–180 ft.—Bluish sandy gravel.
180–230 ft.—Sandy clay.
260 ft.—Gravel.

The shells spoken of so frequently by drillers in this region consist mainly of *Rangia cuneata*, a brackish water

form already spoken of in Special Report No. I. As a rule, we believe these shells are encountered in greatest number about 90 ft. below the surface.

Elevations at which the water stands varies much in pumping season, but perhaps as an average the height of the water in the wells down the track three-fourth mile E. of the station may be taken. March, 1901, the water stood 6 ft. 8¾ in. below the flume of this well. March, 1902, it stood 7 ft. 11½ in. below the same datum point. No spirit leveling was done here, but we believe that from the R. R. track and station elevation, an estimate of 19 ft. A.T. would be about right for the surface of the water.

Jennings, 3 miles E. S. E. of.—Well being put down Feb. 24, 1900, by Mr. Brechner showed:

	Feet
Reddish, yellow and gray mottled clay....	30
Becoming less tenacious with fragments of fossils, *Rangia*, *Helix*, *Balanus*, to........................	90
Blue sand ; for depths not determined...............	

Jennings, 9 miles S. S. W. of.—The region about Jennings being perhaps about centrally located in the region of deep wells for rice culture, a few words of explanation of the methods here used in sinking the same may not be out of place.

On Mar. 3, 1902, I saw a well 211 ft. in depth practically completed in one day. Plate XLII shows the "rig" in operation. The well was about 9 miles S. S. W. or 2 ½ miles N. W. of Lake Arthur.

The process in brief was as follows:

A long pit, perhaps 10 ft. wide by 20 long, was dug or scraped for a temporary reservoir. This was divided into two compartments, connected, however, in one or two places.

The derrick erected and engine placed, a 3-in. pipe with a broad arrow-head bit attached to one end is hoisted up by rope and drum, and the water hose of equal size is attached to the upper end. By a simple device, this pipe is rotated by power from the engine while water is pumped from the pit just described through the hose, down the

RITTER BROTHERS' WELL RIG AT WORK; DRILLING

pipe into the ground. As the pipe descends, the matter disengaged by the bit is washed out and brought to the surface by the jet. When the pipe, say 12 ft. long, is sunk into the ground nearly its whole length, another section from 12 to 20 ft. long is attached and the rotating and pumping continued till it too is sunk almost to the surface of the ground. And so the 3-in. pipe is put down till by the appearance of the sand, or the feeling of the pipe when rotated, there is an indication that the water-bearing sand is reached.

Mention should be made here of the care shown in one of the compartments of the pit or pool referred to above, to see that plenty of earth or clay is mixed with the water just before it is pumped through the hose into the pipe. The pressure from the engine pumps is sufficient to force this muddy water into the sandy layers and cause them to stand firmly and not cave as they would be sure to do if only clear water was used. It usually occupies the attention of one man to keep the ingoing waters well stirred up and turbid. The other compartment of the pit contains that portion of the water that has just come out from the well, hence contains the drillings, if such they may be called, derived from the well. The same water as it flows into the first compartment is again used after being properly roiled or mixed with soil.

Having attained the desired depth, the 3-in. pipe is removed, section by section, and the 6-in., 10-in., or 12-in. casing is hoisted up and sunk into the hole made by the 3-in. pipe and its arrow-head bit. The hole is often nearly 14 in. in diameter.

The first one, two, or three sections of this large pipe or "casing" are perforated and form the strainer near the bottom of the completed well. If the strainer is to be three lengths long, say 60 ft., care is taken to insert in the casing three lengths of 3-in. pipe and to fill the space between this inner and the outside pipe so that it cannot fill with earthy matter while descending. Length after length of casing is screwed on and lowered until the

desired amount is sunk into the ground. In case it does not descend readily of its own accord, resort is had to rotating the casing by machinery precisely as the 3-in. pipe was rotated in the beginning. The lower margin of the casing is cut like saw teeth, so, that it answers fairly well as a drill or auger. The upper end of the 3-in. pipe within, carries a conical sleeve, so that it can be caught readily by the thread end of other lengths that are lowered afterwards and coupled up with the three lengths already spoken of as being in the strainer part of the casing. The shavings can now be jetted out, the interior pipe withdrawn, and the well "pumped" to withdraw all the muddy impurities forced down while drilling as well as fine sand that might eventually fill up the strainer.

This well was put down to 232 ft. primarily, but the casing was lowered to 211 ft. only, for fear of the clogging effect of the fine sands below the 215 ft. mark.

The section here observed was as follows:

Soil and sub-soil	3 ft.
Yellow clay	8 ft.
Tough clays, bluish	80 ft.
Sands and gravel	125 ft.
Fine sands	6 ft.+

Flakes of shelly matter at a depth of 200 ft. were not uncommon. They seem to belong to *Mactræ.* Rotten wood, *Rangia*, and *Unio* occur at depths of 90 to 100 ft. in wells hereabouts. Plate XLIII shows how, after the well is cleared of shavings, the fine sand is pumped out and the well made to yield its greatest supply, before being paid for by the owner of the place. In other words, the well is being "tested."

Lake Arthur, 1½ miles N. W. of.—This reference is to R. E. Camps' well, S. E. ¼, Sect. 8, 11 S., 3 W.; Depth, 215.7 ft.; water-bearing sand, 40 ft. thick.

Elevation: top of pipe, 17.5 ft. A. T. as determined by spirit leveling from Lake Arthur. Water surface, 8 ft. A. T.

Lake Arthur, 5 miles N. of.—Three wells in a row.

Elevation: top of pipe, 16.5 ± ft. A. T. (Lake Arthur), water in well about 7.5 ft. A. T. Feb. 24, 1901.

BRECHNER RIG : TESTING A WELL

Shell Beach.—We were not able to call at this place, but know that there are several flowing wells here. On the opposite side of Lake Arthur wells are said to flow fully 5 ft. A. T.

Welsh, E. L. Brown's well, center of Sect. 30.

Section :

Clay	to....	65 ft.
Sand growing coarser below	to....	130 ft.

Elevation : water stood 6.82 ft. below top of rail in front of station, Feb. 26, 1901 = about 25.18 ft. A. T.

Welsh, ½ mile E. of, Cooper's well.

Section :

Clay	to....	90 ft.
Coarse sand, clay, sand and finally blue sand at a depth of		140–145 ft.

Welsh, ¾ mile E. of station, Field's well.

Section :

Clay	to....	90 ft.
Sand, coarse below	to....	164 ft.

Elevation : of water, Feb. 26, 1901, 25.38 ft. A. T., *i. e.* 6.62 ft. below station.

Welsh, 2 miles S. E. of, north well, Abbott's place.

Elevation : water surface, Feb. 26, 1901, 7.08 ft. below R. R. station or about 24.9 ft. A. T.

Welsh, 9 miles N. N. W. of.

Section :

Clay	to....	190 ft.
Sand	to....	235 ft.

Welsh, 1½ miles, Herald's well.—Perhaps 1½ miles E. S. E. of the station.

Elevation : Water stood, Feb. 26, 1901, 6. 9 ft. below station, or about 25 ft. A. T.

Kinder, 1 mile N. of, McRill's well.—Depth, 150 ± ft.

Elevation : of Kinder, 49.3 ft. A. T.; water surface, 27.1 ft. A. T., Mar. 8, 1902.

Kinder, Tillotson's well.—Depth, 138 ft.; depth to water from top of pipe, 21 ft. 10 in.; temperature, 68°.

Elevation : of water, Mar. 7, 1902, 25.4 ft. A. T.

China, McBirney's wells.—A number of wells in this vicinity ranging in depth from 140 to 175 ft. and in size from 6 in. to 8 in., in which water rises to within 14 to 23 ft. of surface depending on local topography.

Oberlin.—Mr. Dennis Moore says that the R. R. tank well is 190 ft. in depth, and that water rises to within 10 ft. of the surface, or about 60 ft. A. T.

We are inclined to think that in general the water level would be somewhat lower than this. No hopes can be entertained of obtaining a flowing well at these comparatively shallow depths.

Lake Charles, 1 mile N. of.—The Bradley and Ramsay Lumber Co. well, about 500 ft. deep, has the greatest flow of any well we have measured in the state, 210 gal. per minute; pipe 6-in.

See analyses given below.

Elevation: 10.5 ft. A. T. (Based on tide gauge reading at Lake Charles, by G. D. H.)

Lake Charles, Reiser's Machine Shop well.

Section:

Sand	to....	96 ft.
Red sand with pebbles	to....	102 ft.
Grey sand and clay alternating	to....	200 ft.

Water with irony taste. See analysis given below.

Elevation: of well about 13 ft. A. T.; known to flow to 17 ft. A. T. and said to have flowed to 27 ft. A. T.

Lake Charles, Judge Miller's well.—Pressure of 5.25 pounds per sq. in.; flows 12 gal. per minute.

Elevation: of present flow, 12.72 ft. A. T.; would flow at 24.79 ft. A. T.

West Lake, Perkins and Miller Lumber Co.'s well.—Pipe, 4-in.

Elevation: Flows 10 ft. A. T. and would doubtless flow 16 ft. or more A. T.

West Lake, 3 miles N. W. of.—Pipe, 8-in.

Section:

Hard clay met between		250 and 350 ft.
Shells	at	300 ft.
Gravel	at	360 ft.

This is a very strong flowing well.

Vinton.—Well reported as 540 ft. deep, with a flow of 33 gal. per minute.

Sour Lake, Texas, 4 miles E. S. E. of.—Depth, 1915 ft.; pipe, 4-in.; flow, 90 gal. per minute; temperature, 84°.

This well is said to have passed through a sticky green clay and encountered a rock bed on which the pipe is now standing. The water comes from just beneath the rock. The washings from the bottom of the well are light greenish sands with fine fragments of shells. The whole reminds us of Miocene Tertiary, though specimens are too fragmentary for sure identification.

The temperature of the water from some of the wells at Sour Lake is said to be over 100°.

VARIATION OF HEIGHT OF WATER IN DEEP WELLS

How determined.—Mr. Pacheco was in the field in S. W. Louisiana during the months of February, March, April and May, 1901, and February and March, 1902, keeping a record of the variation in the height of the water in the deep wells of that region, previous to the pumping season. Of the results obtained, only those concerning a few of the wells observed need be given, as they are fairly uniform for the whole region in question.

The measurements were taken by means of a weighted tape line graduated to inches and fractions thereof, and the tables appended give distances from the top of the pipe down to the water level.

Results.—As will be seen by the records appended, the water in these wells rose in the pipes until about the last part of April, 1901, when it reached its maximum observed elevation. From that time on, and coincident with the opening of the pumping season, it began to subside, at first slowly and more or less irregularly and then faster and more steadily as more and more wells began to be pumped, until it dropped below the pumps and no further measurements were possible.

The influence of pumping on the height of the water in the wells is well shown in the case of both Hammil's and Lawson's wells at Jennings. The former is situated about 2½ miles south

of the R. R. station and the latter 1 mile E. by the R. R. tracks. Although pumping had not begun in the neighborhood of those wells until the middle part of May, they began to decline at about the same time as the rest, although not so abruptly.

The lasting effect of the intense and steady pumping, combined no doubt with the excessive dryness of several months preceeding, is accountable for the low stage of the water of these wells even as late as February and March of 1902, just about a year after the first observations were made; none of these wells having yet reached the same height as at the corresponding date of the previous year.

VARIATION OF HEIGHT OF WATER IN HAMMIL'S WELL, 2½ MILES SOUTH OF STATION, JENNINGS, LA.

1901.		Ft.	In.	1901.		Ft.	In.
Feb. 21.		13	4	Apr. 29.	a.m.	13	7.2
Apr. 20.		13	9.5		p.m.	13	7
21.	a.m.	13	9	30.	a.m.	13	7.16
	p.m.	13	8.5		p.m.	13	7.12
22.	9 a.m.	13	7.25	May 1.	2 p.m.	13	7
	11 a.m.	13	7		4 p.m.	13	6.9
	12 m.	13	6.9		5 p.m.	13	6.8
	2 p.m.	13	6.87	5.		13	7.75
	3 p.m.	13	6.75	6.	a.m.& p.m.	13	7.75
	5 p.m.	13	6.75				
24.		13	8.75	14.		13	10.25
25.		13	8	15.		13	11
26.	a.m.	13	8.33	16.		13	11.75
	p.m.	13	8.25	17.		14	0 125
27.	10 a.m.	13	8.5	18.		14	2
	11 a.m.	13	8.4	20.		14	2
28.		13	7	Water dropped below pump.			

VARIATION OF HEIGHT OF WATER IN LAWSON'S WELL, 1 MILE EAST OF STATION, JENNINGS, LA.

1901.		Ft.	In.	1901.		Ft.	In.
Apr. 21.	10 a.m.	6	5.75	May 2.	10 a.m.	6	6.25
	6 p.m.	6	4.12	5.	3 p.m.	6	7.25
22.	8 a.m.	6	4		3:30 p.m.	6	7
	6 p.m.	6	3.9		6 p.m.	6	6.8
23	8–11 a.m.	6	4	6.		6	6.83
24.	p.m.	6	4.37	18.		7	5.25
25.	7 a.m.	6	4.2	19.		7	3.5
26.	a. m.	6	4.37	20.		7	2.87
	p.m.	6	4.33	22.		8	
27.		6	4.75	24.		8	
28.	9 a.m.–4 p.m.	6	5.33	1902.			
29.	8 a.m.	6	5.8	Feb. 22.		7	10.25
	2 p.m.	6	5.75	23.		7	10.25
	6 p.m.	6	5.66	25.		7	9.75
30.		6	6	26.		7	8.5
May 1.	9 a.m.	6	6.12	27.		7	8.25
	11 a.m.	6	6.12	Mar. 11.		7	9.25
2.	8 a.m.	6	6.12	13.		7	9.125

WELSH, BOWER'S WELL

1901.		Ft.	In.	1901.		Ft.	In.
Feb. 26.		4	6	May 12.		4	2.5
Mar. 21.		4	3	13.		4	2.75
Apr. 20.		4	1.25	14.		4	2.75
23.		4	1.5	15.		4	3.5
24.	8 a.m.	4	1.4	16.		4	3.75
	10 a.m.	4	1.5	17.		4	3.75
	11 a.m.	4	1.6	18.		4	4
	12 m.	4	1.75	19.		4	4.25
May 3.		4	1.75	20.		4	4.5
5.		4	2	21.		4	5
6.		4	2	22.		4	5
7.		4	1.75	25.		4	7
8.		4	2.12	26.		4	9
9.		4	2.12	28.		5	5
10.		4	2.12	30.		5	9
11.		4	2.25				

FENTON, LA., HAWKEYE RICE MILL

1901.		Ft.	In.	1902.		Ft.	In.
Mar. 31.		14	10	Mar. 7.		18	3
May 5.		15		8.		18	2

REPRESENTATIVE VIEWS ON THE SUBJECT OF WELL VARIATION

Last season, (1901), was one of unusual dryness in Louisiana, and especially during the months of May and June and consequently nearly all wells were pumped most vigorously in order to furnish a sufficient supply of water for irrigation purposes. The following communications have a special bearing on the subject for the season of 1901 :

Covington, La.—Mr. Robert Wallbillick, Covington, La., writes under date of Oct. 1, 1901, regarding the behavior of wells near Covington as follows : "I have not noticed any decrease in the flow of wells during the last few summer months, *i. e.* the deep flows."

Opelousas.—Letter of L. E. Little, Opelousas, La., October, 1901, states that the four deep wells in the vicinity of Opelousas are from 135 to 155 ft. in depth; that the water rises to within 35 to 45 ft. of the surface; and that the wells furnished the usual amount of water during the dry season of 1901.

Gueydan.—J. P. Gueydan quoted. October, 1901. "There are at present about 50 wells in Vermillion parish, most of which are located near Gueydan. During the summer 1901 they gave entire satisfaction, furnishing an abundant supply of water and were lowered only 2 or 3 ft. A deep well for water should be bored until the stratum of gravel is reached, (about 170 ft. here), and then as many more feet as the length of the strainer that is to be put in the well, usually about 50 to 60 ft. This would bring the well down to a depth of about 230 ft. Should the strainer be in sand instead of gravel, (we call them here "cheap wells"), the well would be checked after using one season. Ten or twelve inch casting is now very popular. It has been demonstrated that a larger and better quality yield is obtained from well water than from bayou water. The supply equalled the demand where one 8-in. well was used to irrigate 160 acres. Pumping began in the later part of May and ended only in September. But steady consecutive pumping was not necessary during the whole time. Salt water did not appear in the wells, but the bayou Queue Tortue water was salty for ten days. It is expected that about 100 wells will be sunk here in 1902."

Lake Arthur.—Letter of R. E. Camp, Lake Arthur. States that well levels were apparently lowered about 8 ft. by the pumps during 1901; no salt water appeared; one 8-in. well irrigated 100 to 150 acres.

Crowley.—Letter of Oct. 1, 1901, from G. S. Mann, Crowley, La. Reports that wells from 180–210 ft. deep were lowered during the summer; that the supply was not at all times equal to the demand. Pumping lasted from June 15 to Sept. 15. No salt water appeared. The capacity of wells has been overestimated. An 8-in. well would water 50 or 60 acres. Wells 300 ft. deep were not lowered during the summer. There is a superiority of one well over another.

Jennings.—Letter of October, 1901, by J. F. Ritter, Jennings, La. states that the surface of the water was lowered from 8–12 ft. during the busiest pumping season; that the extreme limits of pumping was from May 15 to Sept 15; that the supply fully satisfied the demand; that salt water appeared "no more than usual;" that many wells will be put down in 1902.

Welsh.—Letter from C. M. Field, Welsh, La. states that from May 3 to May 24, the water level in the well dropped from 7 ft. 7 in. to 8 ft. below his datum point; from June 6 to June 16, the drop continued, being from 10 ft. to 12 ft. 8 in. when it passed below his pump and hence could not be directly measured. He estimates it stood from 5 to 4 ft. below his pump. About Sept. 25 it again appeared in the pipe 12 ft. 8 in. below his datum point.

Welsh.—Letter from Mr. Bower, Welsh, La. states that the surface of the water in his well was 4 ft. 1¾ in. on May 3, that the surface gradually lowered during the earlier part of the month, standing at 4 ft. 4 in. on the 18th; the latter part of the month showed a much more rapid lowering, so that May 30 the surface stood at 5 ft. 9 in. below his datum point.

Fenton.—Letter of Oct. 13, 1901. By Q. J. Mills, Fenton, La.: "The water level had gone down about 8 in. before we commenced pumping, May 26. In a very few days after we began to pump the water went below the pump and we had to prime it. But after the pump was primed, we got as much water as before. We irrigated 300 acres with one 10-in. well, and

we are now threshing the crop, which is making a yield of 14 bbl. per acre. We could not measure the water in our well during the summer after it went below the discharge pipe, but from reports from other wells we think 8 or 10 ft. is about the true lowering of the water level."

China.—Letter of Mar. 15, 1902, by Bert McBirney, China, La.: "During the first two or three weeks of our pumping the water lowered about five ft. and stood at about the same level during the rest of the season. The water would rise two or three ft. if we stopped pumping for a few days. But upon pumping, again, the water would lower again to the extent mentioned above. The water now stands about 15 ft. below the surface, the same as it did last year. The extent to which the water lowered last year depended greatly on the well; the wells that were put down far into the ground and had good coarse screens were affected but very little. The wells I described above are the average wells of the vicinity."

Lake Charles.—Letter of Oct. 10, 1901, by A. V. Eastman, Lake Charles, La.: "During the drouth last summer the water in the deep wells was from 6 to 12 ft. lower than during the winter and spring; and it is a fact that after we had a very heavy rain in July the water rose again to the same extent, and it is now considerably higher than during the drouth."

In Mr. S. L. Carey's remarks before the Rice grower's Convention, at Lake Charles, Feb. 14, 1901, he said: "After trying 500 wells, 300 new, during the past season, which has broken all records for drouth and heat, we can claim success and victory for irrigation by wells.

"Rainfall has been short nearly 20 inches each for the past two years, and May and June, which for 30 years have averaged 6 in. each, May, A. D., 1901, gave us only 0.35 of an in., and June barely one in. Is it any wonder the water level fell 10 to 12 ft., necessitating that much lowering of the pumps. But the water was there in full supply. This made a change of pump necessary to submerge for priming. But notwithstanding all the difficulties success was assured."

DETAILED STUDY OF EFFECT OF PUMPING AT MEMPHIS

Mr. Pacheco has been able to note the general effect of pumping in wells at cousiderable distances from each other as noted above. That the wells lowered greatly by the season's pumping is likewise manifest from the above communication. But we have not had at our own disposition the management of wells, say a few thousand feet apart, so as to watch with care the effect of pumping so far as regards the water level of one and all the wells.

The Report on the Water Works System of Memphis, Tenn. by Jno. Lundif, 1898, contains interesting facts on this subject that may be of interest to well men in general. He says, (p. 16):

"If all pumping were stopped, and sufficient time allowed to elapse, the water would rise in the wells to its static level. If the underground supply were a free reservoir of water under constant head, the time elapsing before the static head was reached in the wells when pumping was stopped would be very short and simply dependent on the resistance encountered to flow in the well tubes and the quantity required to fill them, together with the pump well. As obstruction increased by the water requiring to filter through the sand in seeking the wells, the time required to reach a static condition would be greater.

"Thus, the extent of area drained by the wells is indicated by shutting down the pumps and noting the rate at which the water rises in seeking its static level. Were the underground and well conditions known accurately, the area drained could be calculated from this rate of rise; and on the other hand, if the area drained could be determined by another method, the general underground and well frictions would become determinate.

"It has been possible to adapt both methods of investigation in the case of the wells at Memphis. First, by shutting down the pumps at the station, which was done on the morning of Mar. 6, 1898, at midnight, and noting the levels at close intervals of time of the water as it rose in the station standpipe connected with the pumping well. The result of this test is shown in Fig. 24, from which it will be noted that the water rose to a level of thirty feet over where it stood when pumping was stopped, with remarkable rapidity, after which it rose more slowly, showing that at first the water was forced up through the wells under the action of considerable pressure, indicating a correspondingly high head in the immediate vicinity of the wells; after which, it was evident that the water had to percolate from a greater distance through the sand under the influence of a more and more distant head. The curve of rise indicates first an inerita effect due to starting the water in motion, then a rapid rise due to the head in the immediate vicinity of the wells, and then a gradual diminishing flow.

"The curve of rise of the water under similar conditions observed at the

pumping station Oct. 25, 1891, before the 10-in. wells were sunk, is also shown on Fig. 24.

"A comparison of these two curves indicates that the head in the immediate vicinity of the wells was greater at the time of the test in 1891 than at the time of the recent test, and also that the slope of the artesian water surface was greater in 1891 than now. This may be accounted for partially by the fact that there are now many more wells in operation in Memphis than then, and a correspondingly greater draft is being made on the water

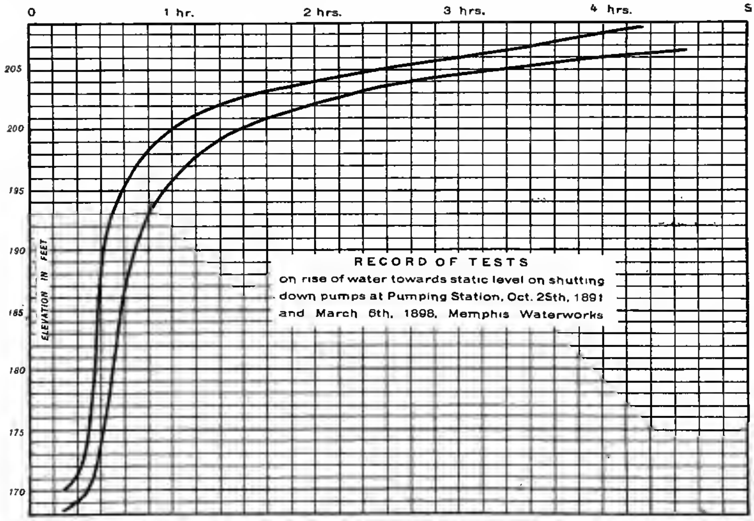


FIG. 24.

borne by the artesian sand stratum, which results in a lowering of the general head of the artesian hydraulic surface.

To obtain the slope of the artesian hydraulic surface in the vicinity of Memphis, recourse was had to measurements on wells not connected with the waterworks system, by having the pumping stopped from such wells and giving the water sufficient time to rise to approximately its static level. Pumping was of course going on from the waterworks wells during these observations.

"Fig. 25 shows the static level so observed of various outlying wells while the level of the water in the waterworks wells remained at the level shown. The level of the water in the waterworks wells is shown over the origin of the diagram, and the levels of the outlying wells at their respective distances from the nearest operative well of the waterworks system. A curve traced through these points shows remarkable uniformity and

indicates the water slope towards the area drained by the waterworks wells.

"The fact is proven that at a distance of from five to six hundred feet from any of the waterworks wells the level of the artesian water plane has

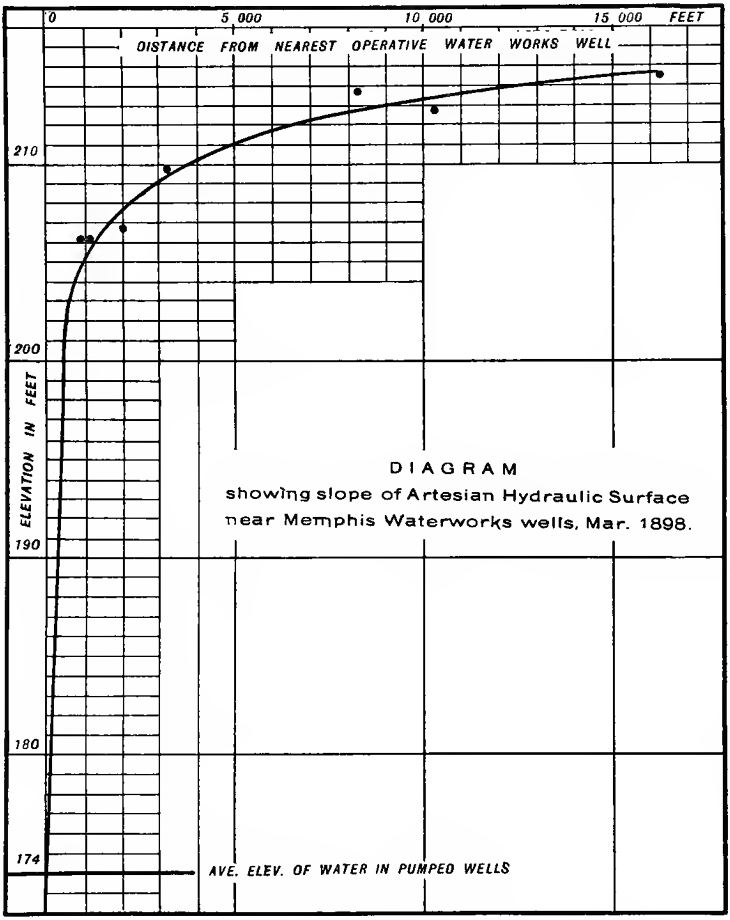


FIG. 25.

risen to such an extent as might justify the sinking of the additional wells.

"It will be noted that the elevation of the water in the wells gauged nearest to those of the waterworks system corresponds to the level to

which the water rapidly rose on making the test at the pumping station already referred to, and the slope of the water plane from that point back, correspouds as to distance to the rising level in the station standpipe during the test plotted on time intervals. From these two curves interesting results may be deduced mathematically as to resistance to flow in the water bearing stratum. For purposes of this report however, the evidence is conclusive as to the abundance of the supply and also as to its permanency."

ANALYSES OF ARTESIAN WATERS FROM SOUTHERN LOUISIANA

Parts per million.

Names of wells.	Locality.	Solid matter.	Ash.	Organic matter.	Free ammonia.	Albuminoids.	Nitrates.	Nitrites.	CaO.	P_2O_5.	K_2O.	Remarks.
A. A. Bayer....	Mandeville.	208.40	178.4	30.0	0.04	0.14	0.8	trace	4.0	1.19	4.14	Colorless, with little suspended matter.
Moresi.........	Jeanerette	480.0	400.0	80.0	0.10	0 96	0.50	.02	39.40	0.64	6.62	Very cloudy.
Moresi (barnyard)	Jeanerette	417.8	366.8	51.0	1.66	.02	1.0	trace	91.0	4.84	7.95	Cloudy.
E. Dessome's at flower garden	Mandeville	179.4	150.4	29 0	.09	.06	0.2	trace	2.40	0.59	6.46	Perfectly clear.
Mrs. Aubert....	Abita Spring	184.0	154.0	30.0	.05	none	0.24	.06	0.7	0.74	4.80	Perfectly clear.
Hermandez by house	Covington	161.6	133.0	28.6	.08	none	0.4	trace	15.4	0.69	8.27	Colorless, with little suspended matter.
Frederick still..	Covington	139.0	117.0	22.0	.01	none	0.72	none	——	0.48	7.34	Colorless, with suspended matter.
Lockmore & Co.	{ West Lake { LkCharles	268.0	214.0	54.0	.01	0.10	0.20	none	44.0	0.42	3.16	Colorless with suspended matter (fishy smell).
Bradley and Ramsey Co...	LakeCharles	245.0	219 0	26.0	.09	none	0.20	none	36.0	0.21	4.33	Whitish cloudiness.
Reiser machine shop.........	LakeCharles	260.0	235.0	25.0	.08	none	0.52	trace	46.5	0.25	3.94	Whitish cloudiness.
Menafee Lumber Co........	LakeCharles	271.4	235.0	36.4	0.18	none	0.32	none	33.3	0.42	2.52	Slightly cloudy.
Judge E. D. Miller........	LakeCharles	277.0	229.0	48.0	0.11	none	0.32	none	48.2	0.42	2.56	Slightly cloudy.
Oak Hotel.....	Hammond	185.0	144.6	40.4	0.14	0.16	0.80	.001	5.0	not enough to determi'e	6.98	Colorless, with suspended matter.

ANALYSES OF ARTESIAN WATERS FROM SOUTHERN LOUISIANA

Parts per Million

Names of wells.	Locality.	Solid matter.	Ash.	Organic matter.	Free ammonia.	Albuminoid ammonia.	Nitrates.	Nitrites.	Lime.	Potash.	Phosphoric acid.
Dr. Robinson..........	Hammond	187.0	152 0	35.0	0 014	0.10	0.28	trace	6 00	3.49	0 216
Owl Bayou Cypress Co...	Strater Station	619.0	533.4	85.6	3.08	0.50	0.38	trace	43.30	3.91	2.90
Ponchatoula Town well	Ponchatoula	205.0	179.0	26.0	0.07	none	0.48	trace	2.00	1.02	1.28
Beigal's over flow (232 ft. deep)	Ponchatoula	237.0	198.0	39.0	trace	0.205	0.80	0.60	11.50	6.40	1.48
Beigal s Pump well (100 ft. deep)	Ponchatoula	512.6	450.0	62.6	1.98	0.20	1.00	0.40	2.0	11.64	10.24

SPECIAL REPORT
No. VII

THE TIDES IN THE RIGOLETS

By R. A. Harris, Ph. D.

(U. S. Coast and Geodetic Survey)

THE TIDES IN THE RIGOLETS

The tides in the Gulf of Mexico are remarkable for the size of their diurnal constituents. In fact, along the Gulf coast from western Florida to Yucatan, the diurnal wave is so much larger than the semidiurnal, that at most places only one high water and one low water occur during a lunar day, especially when the declination of the moon is considerable. The semidaily wave is due chiefly to two causes: the disturbance produced by the tidal forces acting upon the waters of the Gulf and the disturbance produced by the Atlantic Ocean acting through the Straits of Florida. Because of its smallness, the semidaily portion of the tide will not be further noticed in this paper. The diurnal portion of the tide is due to a stationary wave found in the canal-like basin composed of the Gulf of Mexico, the Caribbean Sea, and the connecting basin. The open end of this canal is marked by the Windward Islands. The rise and fall of the Atlantic Ocean in this vicinity produces the stationary wave just mentioned and this wave accounts for the fact that diurnal high or low water is nearly simultaneous over the Gulf of Mexico. Of course the tide at places situated upon those comparatively small bodies of water which communicate with the Gulf, occurs somewhat later. For instance, the time required for the tide wave to traverse Mississippi Sound and Lake Borgne as far as the east end of the Rigolets is about five hours,—judging by the depths of the water and noting the probable delaying effects at Cat Island Channel and Grand Island Pass. According to the Coast Survey Tide Tables, it is diurnal high water in that portion of the Gulf which lies between Mobile Bay and the mouth of the Mississippi River about four hours before the moon passes over the meridian of this locality, her declination being nearly extreme north. Near the times of extreme southern declination, the lower transit of the moon should be used in place of the upper. We should therefore expect high water at the entrance to the Rigolets to occur at about one hour after the time when the moon crosses the merid-

ian, the declination being near a maximum. The consideration of conserving and losing wave energy leads one to infer that the amount of rise and fall should be increased along the shelving border to the deep portion of the Gulf, but afterwards diminished in bodies connected with the Gulf by passes. According to the Coast Survey Tide Tables, the range of the diurnal wave at Port Eads, near deep water, is 1.7 feet; at Cat Island Light it is 2.0, and at Biloxi, 2.2 feet. By the time the tide reaches the entrance to the Rigolets the range should be considerably less than the range at Biloxi or Cat Island Light.

Let us now attempt to infer the tidal movements in the Rigolets and Lake Pontchartrain. The length of this lake is 40 statute miles and the area about 603 square miles. The average depth is about 10 feet. Two passes, remarkable for their depth, connect the lake with Lake Borgne. The first is the Rigolets eight and three-quarters miles long and whose smallest cross section is about $1,500 \times 30 = 45,000$ square feet. Fort Pike Light is near the west end of this pass and a railroad crosses near the east end. Off Fort Pike Light the depth is 95 feet. The second is Chef Menteur Pass, seven miles long and having a minimum cross section of about $640 \times 30 = 19,200$ square feet. Its greatest depth is 90 feet. The average depth from shore to shore of either pass is about 30 feet. Depths like these show the eroding or scouring effect of tidal streams.

Assuming the range of tide at the east end of the Rigolets to be a foot or more, it can be shown that true wave motion cannot exist in this rather short pass because too large a portion of the water particles have paths or orbits extending beyond its ends. In true wave motion, the water particles flow half of the time uphill and half of the time downhill. In this short pass they must flow down hill most of the time; moreover, the flow may be regarded as steady during a limited time. If there were no resistance in the pass, Torricelli's theorem would apply and the velocity at the smallest cross section would be

$$v = \sqrt{2g\,(\zeta_{\prime} - \zeta_{\prime\prime})} = 8.0215\,\sqrt{\zeta_{\prime} - \zeta_{\prime\prime}}.$$

feet per second, where $\zeta_{\prime}$, $\zeta_{\prime\prime}$ denote height displacements for the portions of Lakes Borgne and Pontchartrain near the ends of the pass reckoned from mean water level. On account of resistance,

the velocity is, for a pass of uniform cross section approximately

$$v = 8.0215\ \sqrt{\zeta_{\prime} \sim \zeta_{\prime\prime}}\sqrt{\frac{1}{1+0.007565\,\frac{\text{length of pass}}{\text{mean depth}}}}.$$

The coefficient 0.007565 is an empirical number deduced by Eytelwein from experiments made by several parties on the flow of streams. [For long streams the 1 under the radical sign can be neglected and then the formula becomes

$$v = 92\tfrac{1}{4}\ \sqrt{\text{mean depth} \times \text{slope of surface}}\,]$$

For the Rigolets

$$v = 8.0215\ \sqrt{\zeta_{\prime} \sim \zeta_{\prime\prime}} \times \frac{1}{\sqrt{1+11.65}} = 2.25\sqrt{\zeta_{\prime} \sim \zeta_{\prime\prime}}$$

and for Chef Menteur pass

$$v = 2.50\ \sqrt{\zeta_{\prime} \sim \zeta_{\prime\prime}}.$$

These two velocities weighted according to the cross sections of the passes give

$$v = 2.32\ \sqrt{\zeta_{\prime} \sim \zeta_{\prime\prime}}.$$

As an approximation to the truth, we may assume the velocity curve to be a simple sine or cosine curve. We then have for the tidal volume entering or leaving through both passes

$$2.32 \times \text{maximum}\ \sqrt{\zeta_{\prime} \sim \zeta_{\prime\prime}} \times \frac{2}{\pi} \times 64{,}200 \times 44{,}714 \text{ cubic feet.}$$

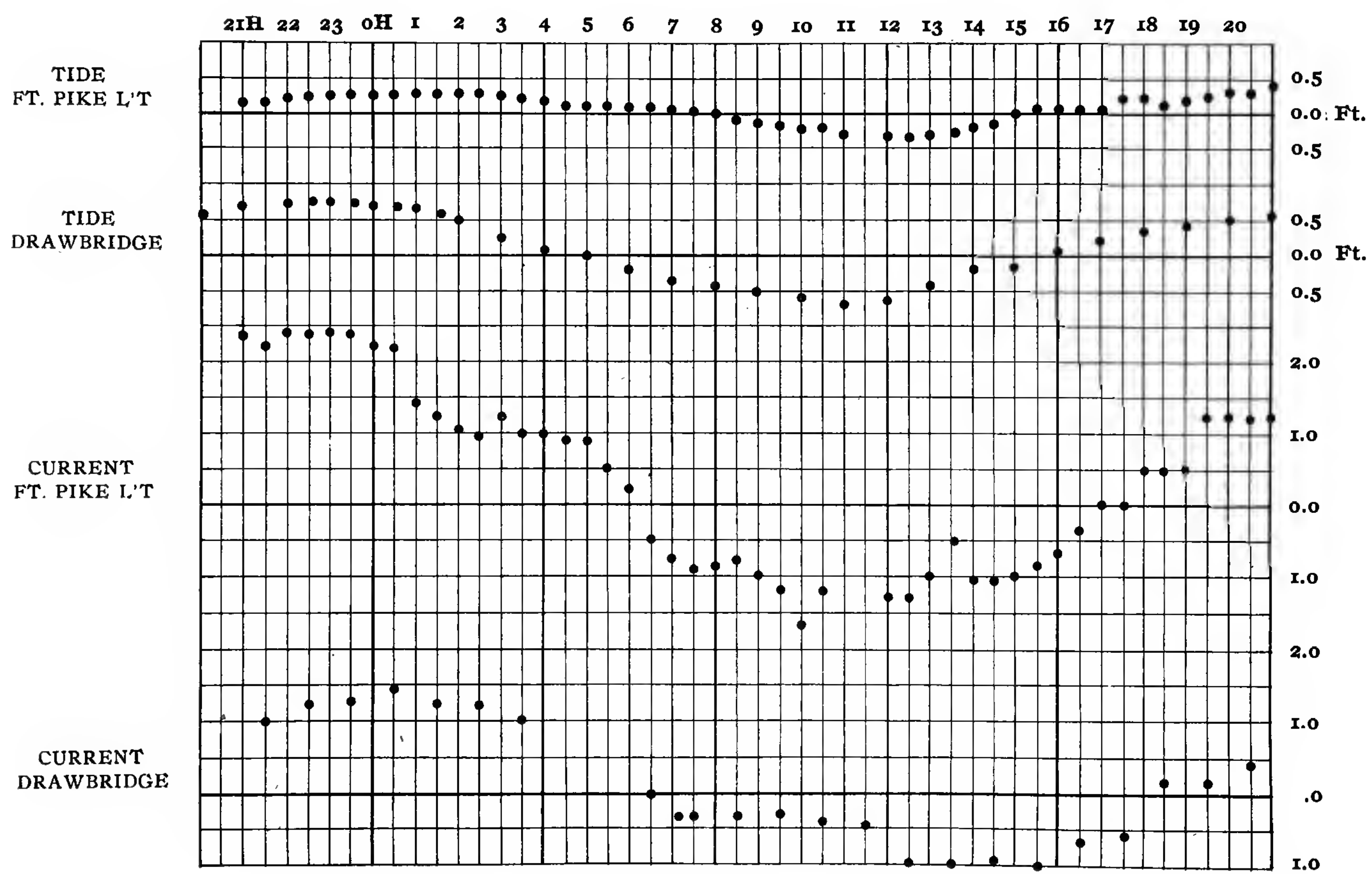
44,714 is the number of seconds in a half lunar day. Upon performing the indicated multiplications, this expression becomes 4,240,000,000 × maximum $\sqrt{\zeta_{\prime} \sim \zeta_{\prime\prime}}$ cubic feet.

This volume divided by the area of the lake gives 0.252 × maximum $\sqrt{\zeta_{\prime} \sim \zeta_{\prime\prime}}$ as the amplitude of the tide in the lake. Consequently this amplitude is about one-fourth of the amplitude outside. The angle whose cosine is this ratio is about 75°, and so slack water in the passes and high water inside occur about 5 lunar hours after the time of high water outside or in the passes. This shows that $\zeta_{\prime\prime}$ is very small at the time of outside high water, and justifies the statement just made about the amplitudes. When the outside range is 1.5 feet, the range inside should be about 0.4 foot. The maximum velocity in the Rigolets computed by the above formula is 1.9 feet per second, and in Chef Menteur pass, 2.1 feet.

If Lake Pontchartrain were several or many times deeper than it actually is, there would then be no sensible wave motion ; that

is, the surface would remain practically level rising and falling according as the water were flowing inward or outward through the passes. In this assumed case high or low water in the lake would occur, according to a computation just made, 5 hours, or nearly one-fourth of a tidal period, later than high or low outside or in the passes. In a shallow body of water, if sufficiently extended, wave motion will be produced; a wave will be generated at the end of this lake near the passes. The inflowing water loses its motion because of the sudden widening and shoaling. The entering volume and the inertia of the waters of the lake produces a slope in the surface of the lake near the passes,—the slope, for a large lake and very small pass, attaining a maximum value at nearly the time of high water outside. At this time the waters of the near or east end of the lake are being most accelerated. According to the theory of wave motion, the water particles in the near end of the lake will attain their maximum velocity one quarter of a tidal period later, and it will then be high water. This indicates that for the east end of Lake Pontchartrain high water should occur when the flood current ceases in the passes or about 5 hours after high water just outside or in the passes. In a similar way the generation of the low-water phase may be considered. To find the time of high water at any other part of the lake, assumed to be shallow, or rather, propagative, we must add to the eastern end time the time of transmission to the point in question. Consequently the tides at the western end of the lake should be about three hours later than at the eastern end, and 8 hours later than outside or in the passes. This delay may be slightly diminished because the lake is perhaps not altogether propagative. On account of the small portion of the tidal period required for a free wave to traverse the lake, the range all over must be almost the same, viz. 0.4 foot when the range at the outer entrances to the passes is 1.5 feet.

On Jan. 29, 30, 1901, tides and currents in the Rigolets were observed for 24 consecutive hours by Professor G. D. Harris and Mr. J. Pacheco. The former made observations at Fort Pike Light, near the inner end of the pass, and the latter at the railroad drawbridge near the outer end. The time used was 90th meridian, which is practically local time. The moon reached


21H 22 23 0H 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TIDE
FT. PIKE L'T
TIDE
DRAWBRIDGE
CURRENT
FT. PIKE L'T
CURRENT
DRAWBRIDGE
0.5
0.0 Ft.
0.5
0.5
0.0 Ft.
0.5
2.0
1.0
0.0
1.0
2.0
1.0
.0
1.0

her greatest north declination on Jan. 30. The times of transit are: Jan. 29, 7 hrs. 48 mins., lower; 20 hrs. 16 mins., upper. Jan. 30, 8 hrs. 44 mins., lower; 21 hrs., 13 mins., upper.

By means of the accompanying plotting of the observations, we see that high water throughout the Rigolets and maximum westward flow, occur 2 or 3 hours after the time of the moon's upper transit. The velocities of the flood, or west-going stream, are written above the axis, and the ebb below. They are expressed in feet per second. At the west end, there were moderate W. S. W. breezes on the evening of the 29th; stiff westerly breeze at 7 A. M. of the 30th; heavy N. W. wind most of the time from 10 A. M. to 9 P. M. At the east end there were light W. S. W. breezes on the evening of the 29th; breezes S. W. on the 30th until 10 A. M.; 10:30 strong N. W. gale lasting until 3:30 P. M.; wind died out at 7:30 P. M.

As neither station is situated where the cross section is a minimum, we should, for this reason, expect the observed velocities to be less than those given by the formula. At Fort Pike Light, however, the observed velocity is probably greater than the average velocity for the cross section there, because of the sharpness of the point around which the current moves.

It will be noticed that the inferred times of the tides in the passes do not excactly agree with the observed times; for, inference makes the tides on days of extreme declination follow the moon by approximately one hour whereas these observations indicate an interval of two or three hours. About 40 minutes of this discrepancy is explained by the fact that diurnal tides are behind their average position with respect to the moon in the winter and summer seasons, but as much ahead in the fall and spring. The remainder of the discrepancy is probably largely due to disturbances caused by the winds.

As might have been expected, the diagram shows that the tide at Fort Pike Light is but little later than the tide at the drawbridge, and not 5 hours or so later, as we have inferred the tide in the eastern part of the lake to be.

SPECIAL REPORT
No. VIII

OIL IN LOUISIANA

BY

G. D. HARRIS

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OIL IN LOUISIANA

INTRODUCTORY REMARKS

Field Work

Our field season in Louisiana closed before Mar. 15, 1902, and, owing to the rapid developments in the state along the oil line since that time, no comprehensive report on the present situation can here be given.

Certain sections were then obtained, and the horizon of certain oil-bearing sands were then determined. Data of this kind will be as valuable to-day or in the future as at any time in the past. Such facts only are herewith offered; they relate mainly to the question of the horizon of the oil-bearing sands.

WELL SECTIONS

New Orleans

We are under the impression that the gas indications in shallow test holes like the Algiers gas well has led to the supposition that oil may exist in paying quantities not far from the surface somewhere about New Orleans. It will be noted that gas was encountered in the deepest wells in New Orleans City, (see previous Report.)

The so-called gas well at Algiers gave the following log:

		Feet
Yellow and dark clayey loam	at	5
Blackish clay	at	11,15,18
Dark clay	at	22,27
Light loamy clay	at	30,33
Dark loamy clay	at	38,40,43,47
Dark clay	at	50
Dark sandy clay with gas and shells, *Arca pectinata*	at	55
Dark sandy clay	at	59,61,63,67,68
Yellowish black sandy clay	at	72
Sand, dark and slightly yellowish and clay	at	73
Yellowish clayey sand	at	80,85,89

There is little doubt, but that the gas here produced is purely local and should in no way be taken as indication of oil.

BREAUX BRIDGE, ANSE-LA-BUTTE

Section of first well sunk : *

		Thickness	Depth
No. 1.	Gravel and sand	100 ft.	100 ft.
2.	Limestone	5	105
3.	Oil-bearing clay with bands of lignite	140	245
4.	Soft limestone	4	249
5.	Oil-bearing clay and gravel	32	281
6.	Salt water, rock salt doubtful	8	289
7.	Oil-bearing clay and gravel	64	353
8.	Oil and water-bearing gravel	11	364
9.	Hard green clay	33	397
10.	Water-bearing sand	88	485
11.	Hard green clay	22	507

The oil is evidently flowing out here on top of the upper Grand Gulf or Frio clays. The salt is presumably dissolved from a source nearby and is transported by the underground waters. Oil actually comes to the surface of the ground in some places. Gas has been escaping here for years. An illustration of the same is given on Plate XI of our Report of 1899.

Since our last report was written, two new well have been put down in the vicinity of Anse-la-Butte. One is on the summit of the little rise of ground at this place. It is shown on Plate XLIV. It has been described at length by Caracristi, who gave a figure of the beds it is supposed to have penetrated.†

He strangely enough gives the Grand Gulf a position above the "Lafayette Drift." Both oil and gas are represented as having their origin well down in the Cretaceous formation.

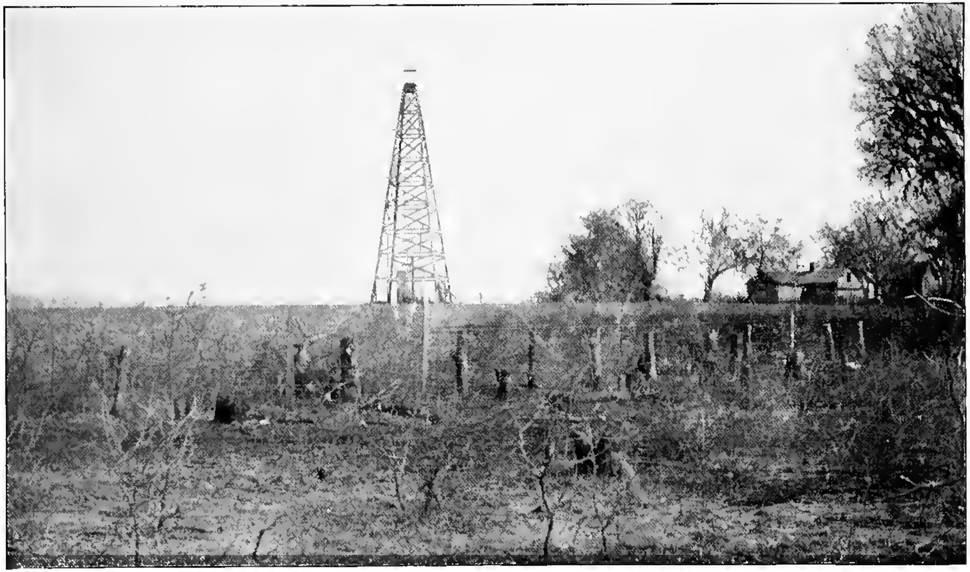
However improperly the different formations may be named

* Section as furnished by Judge Blackman, 1900.

Caracristi gives in addition :

No. 10	Water-bearing sand	88 ft.	to 488
11	Hard green clay	22 "	510
12	Sand and muck	13 "	523

† Report by Dr. C. F. Z. Caracristi on the Holdings of the Anse-la-Butte, (Ledanois), Oil and Mineral Co., Limited, 1891.



ANSE-LA-BUTTE, LA.

in his report, doubtless the log of the well, if taken from samples, or from the driller's notes is a contribution to science.

It reads :

1.	Yellow clay	0 to	37 ft.
2.	Fine sand	37 to	40
3.	Sand, gravel	40 to	50
4.	Sand, coarse	50 to	100
5.	Gravel, fine	100 to	150
6.	Sand, gravel	150 to	200
7.	Sand, coarse	200 to	225
8.	Rock	225 to	226
9.	Oil-bearing sand	226 to	228
10.	Rock	228 to	235
11.	Gravel	235 to	237
12.	Rock	237 to	240
13.	Sand	240 to	242
14.	Gravel	242 to	260
15.	Rock gravel	260 to	265
16.	Oil-bearing sand	265 to	268
17.	Gravel	268 to	285
18.	Sandstone	285 to	290
19.	Hard-pan	290 to	320
20.	Sand-gravel	320 to	350
21.	Gravel	350 to	354
22.	Sand	354 to	364
23.	Shale, blue	364 to	390
24.	Salt	391 to	570
25.	Rock-flint	570 to	576
26.	Gravel	576 to	578
27.	Salt	578 to	790
28.	Sand and gravel	790 to	801
29.	Cap rock	801 to	801½

Gas and petroleum.

What may be called the third well at Anse-la-Butte was drilled early in 1902 about ¾ miles southwest of the one shown in Plate XLIV. On Mar. 12th it had attained a depth of nearly 1500 ft. and the drill had scarcely gone 3 ft. in 24 hours. The material seemed to be very cherty. Between 1415 and 1450 ft. was found the red clay bed described in Special Report No. 1.

From the specimens at the Moresi foundry in Jeanerette and other specimens seen at the well it is quite safe to say that Grand Gulf material was passed through from 800 to 1,500 ft. The section bears more resemblance to the old Lucas well than

to the newer, deeper well reported upon by Caracristi. It is very evident that orogenic movements were very active here at some pre-Quaternary time.

SICILY ISLAND

Boring was going on about 4 miles west of Florence in early 1902. We saw no special indications of oil at that place when passing by to our work on the Ouachita. The general geological section across the state shown by the relief map, Plate II, gives a proper idea of the beds that this well would probably penetrate if continued to a sufficient depth.

BAYOU CHENIERE

This locality is but two or three miles south of a station by the same name on the V. S. & P. R. R., nine miles west of Monroe, Ouachita parish. We saw no indications favorable to the discovery of oil in this vicinity. The first circular by the company embodied facts regarding oil in its property, evidently taken from information regarding wells in the southern part of the state. The total difference in geological structure between the two regions is at once apparent upon examining the geological mapof the state or the north-south sectioned model, Plate II.

JENNINGS

This has proven, so far, the most interesting and important oil district in the state. One of the wells that might have showed perhaps the most geology, if samples had only been carefully saved and recorded, was the *Southern No. 1*, located just west of Bayou Cannes, opposite the mouth of Bayou Plaquemine Brulee. It attained the depth of 2600 ft.,and it is evident from the material taken out, that the usual bluish sands were passed through in the lower part of the boring though the basal beds seem to have a peculiar mottled appearance, reminding one of river deposits, or deposits of shallow fresh water ponds. We believe these lowest beds may be correlated with the Grand Gulf formation.

CROWLEY AND PRAIRIE MAMOU

These are nearly three miles south of the well just described and are located on the Anthony Cochran tract, not far west of

the Bayou Cannes. Neither of these wells were being drilled or pumped at the time of our visit; no statements, regarding the formations passed through, were obtained. But both wells showed clearly that towards, and at the bottom, Pascagoula Miocene beds have been encountered. *Gnathodon* or *Rangia johnsoni* was in evidence at both wells. The Prairie Mamou well was credited with a depth of nearly 2400 ft. while the Crowley well was supposed to be about 2200 ft. deep.

JENNINGS GUSHER

This, the first important well in the region, from an economic standpoint, is located on the fragmentary section 46, 9 S., 2 W., about one-half mile west of the wells just described. It is credited with a depth of 1820 ft. and certainly shows every evidence of yielding oil in abundance. The fossil specimens saved by various individuals, who were on the field during the time of drilling, indicate that the wells down about to the Pascagoula Miocene.

It is useless to attempt any description of the local conditions in this region. Work is progressing at such a pace that those on the ground only can properly follow it. One thing, however, that seems very different here, from the Beaumont region is that

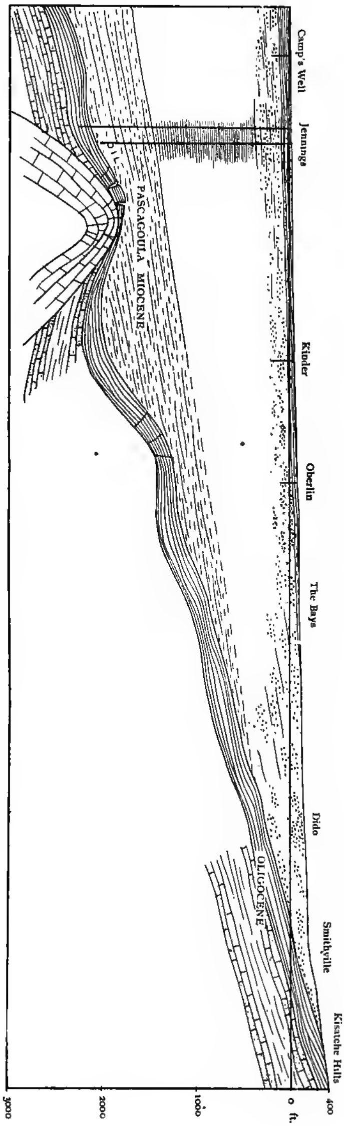


FIG. 27.—STRATIGRAPHY OF JENNINGS OIL FIELD.

the position of the oil is in the Miocene sands. The geological position of the oil is here quite evident for there are fossils to prove it. At Beaumont, thus far, no fossils have been obtained to prove beyond a doubt just where the oil belongs, though the evidence is all pointing towards Cretaceous origin. The original position, or the beds producing the Jennings oil, is probably not the Miocene sands and clays in which the oil is now found. The stratigraphic conditions of this particular region, as they seem to be to us, are shown by Fig. 27. This, however, till more facts are obtained, must be regarded as mainly conjecture, *i. e.*, that portion of the section below the depths of the deepest wells.

SPRING HILL

Mr. J. T. Jackson, the driller of this well, states that he found gravel in abundance to a depth of 1200 ft. He mentions a light sandstone at a depth of about 1450 ft., some 14 ft. thick, that wore the bit out in a most rapid and astonishing way. Below, about 1500 ft., the material brought up is a fine, sharp, quartz sand with green clay flakes. We saw no reasons for supposing oil would be found in this locality.

LAKE CHARLES

Watkins well, No. 1, Sect. 16, 10 S., 8 W., commenced Nov. 20, 1901; completed Feb. 4, 1902. Log from the company's samples:

		Thickness	Depth
No. 1.	Soil, brown loam	2.0 ft.	2.0 ft.
2.	Clay, light, red blotched	9.0	11.0
3.	Fine white sand	39.0	50.0
4.	Light gray clay, shell fragments	21.3	71.3
5.	Light gray sand, fine	16.8	88.1
6.	Bluish gray clay	5.7	93.8
7.	Coarse light sand	4.2	98.0
8.	Slightly brown loamy clay	69.0	167.0
9.	Same as No. 7	4.2	171.2
10.	Light grey clay and sand, few shells fragments (2 in. gravel at 176–8)	273.7	444.9
11.	Sand, fine, coarse and with gravel	145.1	590.0
12.	Same as 8	18.0	608.0
13.	Same as 7 and 9	81.7	689.7
14.	Light loamy, slightly brownish clay	24.2	713.9

		Thickness	Depth
15.	Gray sand	30.2	744.1
16.	Slightly greenish gray clay	84.4	828.5
17.	Fine, slightly brownish sand	83.3	911.8
18.	Grayish and greenish clay	104.5	1016.3
19.	Sand and hard clay	76.8	1093.1
20.	Dark greenish clay	34.1	1127.2
21.	Light sand	58.1	1185.3
22.	Greenish loam	30.6	1215.9
23.	Very fine sand	50.0	1265.9
24.	Gray green loam	197.4	1463.3
25.	Light gray sand	9.5	1472.8
26.	Greenish gray clay	38.0	1510.8
27.	Coarse sand	40.0	1550.8
28.	Gray clay	3.0	1553.8
29.	Fine gray sand	18.2	1572.0
30.	Gray clay	112.1	1684.1
31.	Gray loamy sand	8.0	1692.1
32.	Light sandy clay	22.7	1714.8
33.	Gray sand, little clay	118.3	1833.1
34.	Light clayey sand	8.0	1841.1
35.	Light loamy clay	3.5	1844.6
36.	Light loamy sand	9.0	1853.6
37.	Olive clay	18.5	1872.1
38.	Fine bluish sand	21.0	1893.1
39.	Fine gray sand	39.1	1932.2
40.	Light olive sandy clay	8.0	1940.2
41.	Rather coarse gray sand	97.6	2037.8
42.	Light olive clay	60.0	2097.8
43.	Fine gray sand	12.0	2109.8
44.	Fine gray sand, but more clayey	34.6	2144.4
45.	Gray sand, ferruginous	5.0	2149.4
46.	Gray sand, clayey, saline	5.0	2154.4
47.	Same as 45	8.0	2162.4
48.	Same as 45, but more clayey, not saline	37.7	2200.1
49.	Coarse clean sand	73.1	2273.2
50.	Gray clayey sand	18.5	2291.7
51.	Fine gray sand	39.0	2330.7
52.	Fine gray clayey sand	7.8	2338.5
53.	Fine light gray clayey sand ....to.....		2406.9

We have observed no shell fragments about this well that would indicate anything lower than the upper Tertiary; not even the Miocene *Gnathodon* has been found. Shell fragments consist mainly of small *Mactræ* and the recent *Gnathodon* or *Rangia*.

Hoo Hoo Park well was put down to a depth of 1800 ft. and abandoned.

SULPHUR MINES

We have already devoted considerable space to the description of these mines in southwestern Louisiana; see report of 1899 for figures, plates and descriptions. We present herewith a section taken from samples at the works in 1900:

		Thickness	Depth
No. 1.	Dirt and sand	25	25
2.	Clay and sand	175	200
3.	Quicksand	181–190	380–390
4.	Gravel	25– 60	410–450 ±
5.	Broken rock and limestone	40	490
6.	"Pepper and salt" sands with sulphur crystals	10	500
7.	The same, more sulphur	2	502
8.	Fine, whitish, black-specked sandy layers with grains of sulphur	3	505
9.	Sulphur and gypsum	3	508
10.	Same as No. 8	3	511
11.	Sulphur and gypsum	3	514
12.	Soft, sandy clay and sulphur	6	520
13.	Light gray, fine material and sulphur	6	526
14.	The same, more coarsely crystalline	4	530
15.	Same as No. 12,	3	533
16.	Coarse, dark gray gypsum and crystalline sulphur	3	536
17.	Same as No. 12	10	546
18.	Nearly pure sulphur with some gypsum	22	568
19.	Crystalline sulphur and gypsum	8	576
20.	Whitish soft clay?	4	580
21.	Sulphur and some gypsum	14	594
22.	Same as No. 20	3	597
23.	Sulphur and gypsum	7	604

BEAUMONT, TEXAS

In spite of the many and varied opinions to the contrary, we see no reason whatsoever for abandoning our position regarding the origin of the oil at Beaumont. Historically the following two statements are of interest now, both having been made soon after the discovery of oil in great quantities in Texas.

New Orleans Picayune, Mar. 27, 1901. Communication by G. D. Harris:

"The scanty evidence at hand would therefore indicate that the gusher is situated on top of a Cretaceous anticline or fold, and that the pressure is from gas so commonly encountered in structures of this type. That the supply of oil is considerable, cannot well be doubted, but that it will continue to 'gush' long is very doubtful."

Times-Democrat, May 29, 1901. Communication by R. T. Hill:

"The well-driller may experiment with safety in the Beaumont fields without fear of structural complications, with a reasonable assurance that oil is apt to be found anywhere within the region of the coast plain above the oil-impregnated sands. The oil should be found at decreasing depths at the rate of about seven to ten feet per mile along the line drawn from Beaumont to Oil City, in Southern Nacogdoches county. The pressure and quantity will both likewise decrease away from Beaumont along this line."

Now, in June, 1902, we doubt whether there is a driller in the Beaumont field who is not convinced of the truth of our prediction of a year ago. Mr. Hill of the Guffy Co. remarked that "without doubt Spindle Top is an upheaval. The apex of the dome has been found, in which naturally gas is found in large quantities. The dip, away from this center or ridge is something like 125 ft. to every 500." Again, from the position of the Treadway well, being sunk in March, 1902, and the statements there made that they were in hopes to find oil at 2500 ft., "if the dip remained constant," it is evident that the conditions of this buried short anticline or dome are now well understood. The Treadway well, at the time of our visit, was down 1850 ft. and showed the uppermost Tertiary, or the Galveston well type of *Rangia cuneata*, at that depth. The well one-quarter mile east, still deeper, showed mottled marls, and materials that we feel almost certain should be correlated with the upper Grand Gulf marls.

The slight fold that shows upon the surface runs N. 60° E. by S. 60° W. This we think is produced, to some extent, at least, by the upheaval below.

SOUR LAKE

We have already mentioned the important bearing the facts obtained from this region have on the general subject of the stratigraphy of S. E. Texas (see Special Report No. 1.) The

finding of a good Jackson fauna in one well at 1500 ft., the hot water, the logs of nearby wells showing little resemblance to each other, and the deep well (1915 ft.) about 4 miles S. E. of the village, perhaps down to the Grand Gulf, all tend to make the geologist sceptical of finding oil in large quantities over any great extent of country.

The problem of how to find oil in this portion of the country is indeed a difficult one, for as we have heretofore remarked, again and again, the true structure of the Tertiary and Cretaceous formations is masked by almost level and even bedded Pleistocene deposits. Mr. Putnam has kindly furnished the following log of the well of Atlantic and Pacific Oil Co., the first "gusher" at Sour Lake :

		Thickness		Depth	
		Ft.	In.	Ft.	In.
1.	Sand and traces of oil	47		47	
2.	Blue clay	6		53	
3.	Sand and traces of oil	77		130	
4.	Blue clay	56		186	
5.	Gravel, limestone and pyrites of iron	2		188	
6.	Blue clay, sandstone and pyrites of iron	26	10	214	10
7.	Blue clay, hard on top, softer as drill penetrated	32		246	10
8.	Sand	2		248	10
9.	Blue clay and gravel, slight trace of oil	45		293	10
10.	Mud ("Gumbo")	44		337	10
11.	Rock, apparently boulder, showing trace of oil	1		338	10
12.	Blue clay	10		348	10
13.	Clay and hard shale	20		368	10
14.	Blue clay	4		372	10
15.	Blue clay, with 1 ft. rock at 383–384, considerable gas, slight show of oil	13	2	386	
16.	Rock, hard limestone	5		391	
17.	Mud ("Gumbo") gas and oil traces	7		398	
18.	Blue mud	33		431	
19.	Clay and hard mud	54		485	
20.	Sandstone	3		488	
21.	Limestone	2		490	
22.	Blue clay	3		493	
23.	Mud ("Gumbo") and gravel	34		527	
24.	Blue clay, resembling shale	35	10	562	10
25.	Blue clay, slight gas and trace of oil	15		577	10

	Thickness Ft.	In.	Depth Ft.	In.
26. Blue clay, resembling soapstone, strong gas pressure and good flow of oil..........	52	2	630	
27. Hard clay, resembling soapstone, very strong gas pressure and heavy flow of oil......	5		635	
28. Clay, resembling shale....................	5		640	
At this point (640 ft.) struck oil sand......				
29. Oil sand not passed through	42		682	

Drilling ceased at 682 because of strong gas pressure and heavy flow of oil. Drew drill pipe, during which operation oil gushed through notery, just 20 ft., then 100 ft. high. Eight in. casing set at 642 ft.

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